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AFATL-TR-71-7
VOLUME VI

CLOSE AIR SUPPORT WEAPON ENGINEERING DESIGN STUDY

VOLUME VI. MISSILE SIMULATION

HUGHES AIRCRAFT COMPANY

TECHNICAL REPORT AFATL-TR-71-7

JANUARY 1971

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AIR FORCE ARMAMENT LABORATORY
AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE
EGLIN AIR FORCE BASE, FLORIDA

Close Air Support Weapon

Engineering Design Study

Volume VI. Missile Simulation

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FOREWORD

(U) This report presents the results of the engineering design study of the close air support weapon (CASW) conducted by Hughes Aircraft Company (HAC), Canoga Park, California, during the period from 23 September 1970 to 22 December 1970 under Contract F08635-71-C-0048 with the Air Force Armament Laboratory, Eglin Air Force Base, Florida. The report consists of six volumes, of which this is Volume VI: Volume I - Management Summary; Volume II - Operational Analysis and Warhead Effectiveness; Volume III - System Analysis; Volume IV - System Design; Volume V - Cost Analysis; and Volume VI - Missile Simulation. The contractor's report number is C2448.

(U) The program monitor for the Armament Laboratory was Mr. Vernon L. Reierson (DLWS). The following contractor personnel from the departments indicated were significant contributors to this report: Operational Analysis - Messrs. J. R. Green, W. N. Bragg, G. G. Latta, P. W. Lindsey, and R. H. Martin; System Analysis: Dr. E. S. Ibrahim and Messrs. J. E. Almanza, D. Berman, L. E. Butts, S. E. Milleman, J. H. Miller, J. B. Stonehouse, and L. Wong; System Design - Dr. R. A. Hubach and Messrs. S. J. Goldberg, A. L. Baker, J. C. Kern, D. N. Perper, M. T. Pett, and H. E. Recher; Cost Analysis - Messrs. A. H. Schlueter, R. C. Hendricks, D. D. Lenhart, and K. E. Rufener.

(U) This technical report has been reviewed and is approved.

Randall L. Fetty

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UNCLASSIFIED ABSTRACT

(U) The objective of the engineering design study of the close air support weapon (CASW) was to provide design considerations for the new close air support missile (CASM). The derivation of the missile was undertaken based on the modification of an existing missile. This study incorporates operational requirement and warhead effectiveness studies for various close air support targets leading to warhead and launch envelope recommendations. A thorough analysis of the system performance and terminal accuracy was conducted. Missile simulation models and a system description, including missile, launcher, avionics, and aerospace ground equipment (AGE) are provided. A cost analysis exercise was conducted for the design, development, test and evaluation (DDT&E) and production of the candidate approach. This report consists of six volumes: Management Summary, Operational Analysis and Warhead Effectiveness, System Analysis, System Design, Cost Analysis, and Missile Simulation.

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SECTION I

CLOSE AIR SUPPORT MISSILE SIMULATIONS

1.1 INTRODUCTION

(U) The basic simulation tools used for the CAS weapon system analysis included (1) a basic six-degree-of-freedom simulation digital program, (2) a modified version of the six-degree-of-freedom including a Monte Carlo version, and (3) and a simplified adjoint system model (described in Volume III, System Analysis).

1.2 SIX-DEGREE-OF-FREEDOM DIGITAL SIMULATION

(U) The basic simulation program used in the performance analysis evaluation of the close air support missile system was a six-degree-of-freedom digital computer program which has been constructed by modifying the simulation of the AGM-65A. The objective of the simulation was to provide a complete and intensively detailed representation of the entire missile system which could be used for final design verification, performance evaluation, and spot checks of parameter optimization results from simpler simulations.

(U) The present simulation represents a highly sophisticated and analytical model of the entire missile system. The simulation was developed using the system analysis by digital simulation using analog methods (SADSAM) programming system. This system is used with the FORTRAN IV compiler language and provides an extensive library of functions and operations which lend themselves well to handling the bookkeeping and computational problems of engineering systems. The computational speed of a simulation developed around this system is much greater than one programmed in a more conventional manner.

(U) Wide use has been made of the 6 DOF program in evaluating the system performance, especially as an analytical tool in defining the miss weighting function as affected by heading error, launch velocity, target motion, motor temperature effects, and seeker drift effects.

(U) A listing of the basic 6 DOF programs used in the study together with system nomenclature and input data coefficients is presented herein. This document represents a complete and comprehensive description of the 6 DOF program, including:

1) Program listing
2) Mathematical model description

    a) Block diagram
    b) Parameter definitions

c) Transfer functions where applicable
d) Program input requirements
e) Program flow charts

(U) Figure 1 illustrates a simplified block diagram of the entire simulation model and indicates the depth and scope that have been included in this simulation package.

(U) One of the specific laser seeker model capabilities include the ability to evaluate the effects of laser spot size image variations which cause a variation in the angle-tracking loop gain. Figure 2 shows a typical seeker gain curve varying with range and spot size that has been modeled. The compensation networks, as indicated in Figure 1, can be placed in the seeker forward loop to increase the stability margin and to reduce degradation in angle-tracking response resulting from the effects of spot size growth.

1.3 MONTE CARLO SIMULATION

(U) Paralleling the approach used for AGM-65A performance evaluation, a six-degree-of-freedom digital computer simulation incorporating Monte Carlo techniques has been developed for the close air support missile concept formulation study. For any given set of launch conditions against a particular target, there will be some statistical variation of the miss distance. This results from target designation errors, missile parameter tolerances, uncertainties in the launch conditions, and uncertainties in ambient flight conditions such as temperature and winds.

(U) A statistical description of each parameter is stored in the computer and sampled by a Monte Carlo process which randomly selects a value of each parameter within its own distribution. A homing encounter is then run with this set of parameters and with all error sources present, including tracker noise, seeker drift limit cycle, steering unbalance, and target motion. This results in a miss distance. The process is repeated many times, each with a new set of parameters selected by the Monte Carlo technique. As a result, a distribution of impact points about the aimpoint is obtained, as illustrated in Figure 3.

(U) The Monte Carlo simulation was primarily used to verify results obtained from the adjoint system simulation. The Monte Carlo simulation was used to check the wind disturbance effects obtained from the adjoint. It has also been used to simulate and verify random noise disturbance occurring from tracker noise or designation signal noise.

(U) The results from these simulations are reported in Volume III, System Analysis.

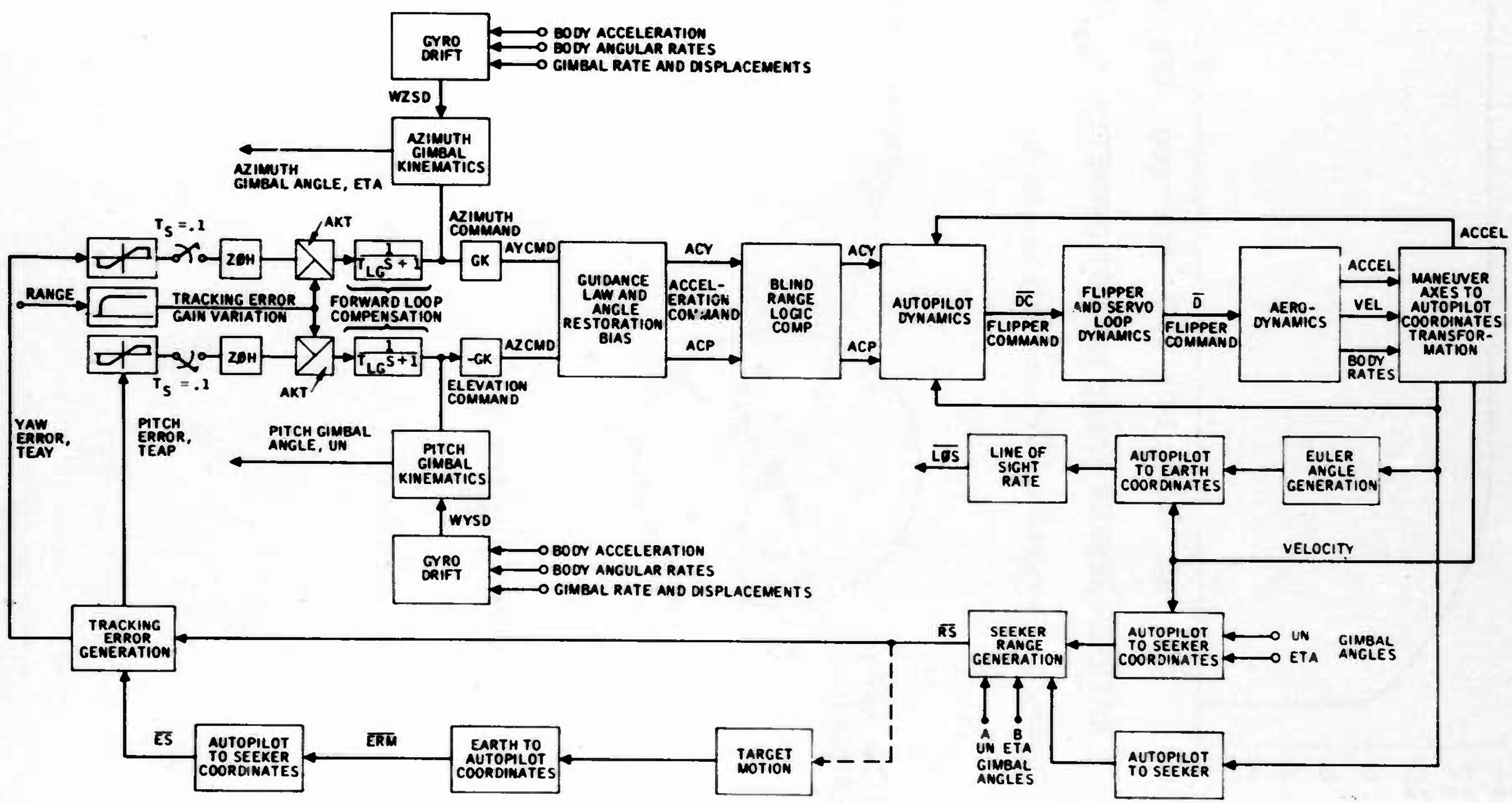

Figure 1. Close Air Support Missile Six-Degree-Of-Freedom Simulation, Simplified Block Diagram

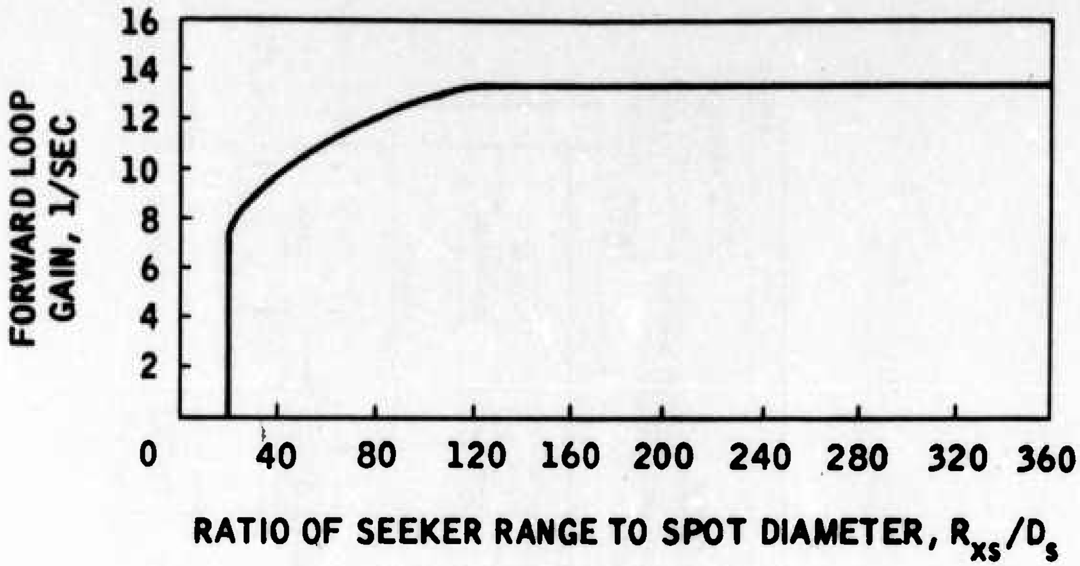

Figure 2. Forward Loop Gain Variation Model

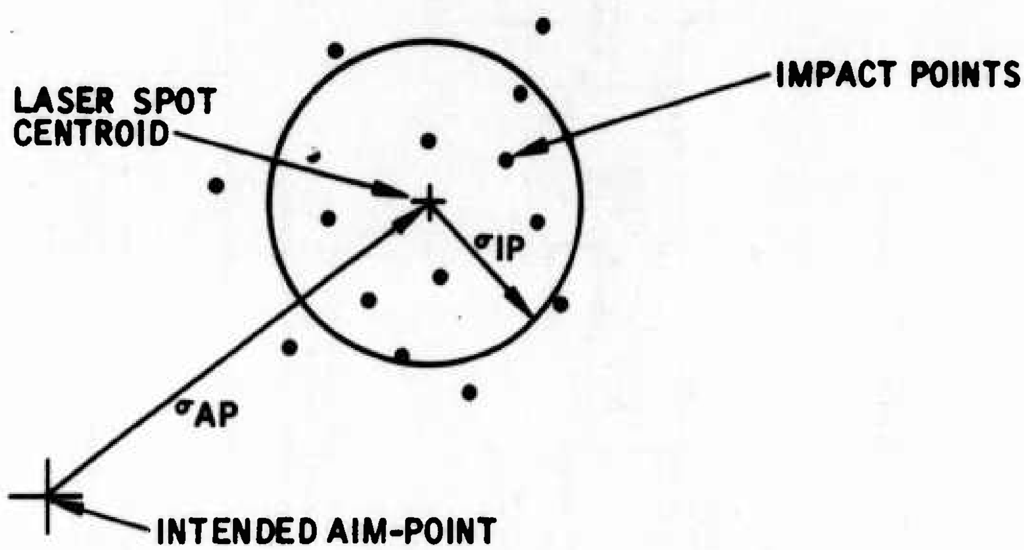

Figure 3. Designation and Impact Point Dispersions

SECTION II

SIX-DEGREE-OF-FREEDOM SYSTEM PERFORMANCE DIGITAL MODEL

2.1 OBJECTIVES, CONCEPTS, REQUIREMENTS, METHODS, AND TECHNIQUES

2.1.1 Objectives

(U) The simulation objectives are to provide a complete and highly detailed simulation of the entire missile system which can be used for final design verification and spot checks of parameter optimization results from simpler simulations.

2.1.2 Concepts

(U) This simulation represents the most complete all-analytical model of the entire CAS missile system. A bare minimum of simplifying assumptions are made in subsystem hardware representation. Seeker drift phenomena are included in their entirety. Autopilot transfer functions are not approximated in any way. In short, this simulation is the best overall missile system dynamics model.

2.1.3 Requirements

(U) The operation of this program requires the use of an object deck, a data deck, and a library of special functions which constitutes a special computational package called SADSAM. All these inputs must be compatible for use with the GE635 Computer.

2.1.4 Methods and Techniques

(U) As previously mentioned, the simulation was developed using a programming system called SADSAM. This system is used with the FORTRAN IV compiler language and provides an extensive library of functions and operations which lend themselves well to handling the bookkeeping and computational problems of many engineering systems. Typical of the available functions or operations are integrations, differentiations, linear transfer functions of almost any order, orthogonal transformations, Euler angle computations, and a variety of non-linear operations such as limiting and backlash. The computational speed of a simulation developed around this system is much greater than one programmed in a more conventional manner.

2.2 DESCRIPTION OF WEAPON SYSTEM EQUIPMENT USED

2.2.1 Introduction

(U) The dynamic performance of the CAS guided missile has been simulated by a digital computer model. The purpose of this section is to describe this model.

(U) The digital computer simulation model is organized in modules and written in FORTRAN IV compiler language. The CAS simulation model makes use of SADSAM III, a programming technique which is specifically intended for dynamic simulations and which achieves both high dynamic accuracy and high speed operation. In addition, it provides preprogrammed subroutines typical of those used in missile simulations, as an aid to the analyst.

(U) The CAS simulation program is organized into four principal modules: (1) universal seeker, (2) autopilot, (3) control surface, and (4) aerodynamics modules. In addition, there are six other minor or supporting modules incorporated into the simulation. These are (1) initial conditions computer, (2) aimpoint wander (target motion), (3) angle restoration bias (guidance law), (4) blind range filter, (5) track, and (6) gyro. Each of the eight subroutines and the main program are discussed in the paragraphs that follow. Also, there is a description of how the model is used as well as a description of the SADSAM programming technique.

(U) Paragraph 2.2.2 provides a brief overall description of the CAS model.

2.2.2 Background

(U) The dynamic model of the CAS missile describes the motion of the missile in three dimensions and makes use of all six degrees of freedom: three positions, three velocities, three attitude angles, and three angular rates. The two vector equations (translation and rotation) applying Newton's Second Law to the rigid missile are rigorously applied, and the kinetic and kinematic behavior of the gimballed seeker is also described in great detail. All significant contributors to seeker drift are represented as well as all significant aerodynamic forces and moments.

(U) The program is arranged in four basic modules describing the seeker, the autopilot, the control surfaces, and the aerodynamics. The modular representation is used because (1) it permits the model to be programmed and checked out more easily; (2) it permits changes and substitutions to be made more easily; and (3) it provides a good correspondence with the actual hardware elements of the missile, so that subsystem specialists can participate in the performance evaluation process in a more direct fashion.

(U) The simulation is exercised by the operator inputing values of all the system constants and setting the initial conditions of the system to the

desired values. Due to the extensiveness of the simulation, numerous inputs are required for a complete initial conditions set. These are provided as the output of the initial conditions subroutine in a form convenient for use in the simulation. The input required for this subroutine establishes the missile configuration at the time of launch and is fully described in paragraph 2.3.3. The simulation begins with all dynamic elements at their steady state conditions. The printout interval and maximum simulation time is also input for each run, and at the option of the operator, any or all the system variables may be printed in any sequence.

2.3 DESCRIPTION OF DATA USED IN SIMULATION

2.3.1 Coordinate Systems

(U) Four different coordinate systems are in use in the simulation: (1) earth, (2) missile body (control surface), (3) autopilot, and (4) seeker. Earth coordinates are simply fixed in inertial space with the missile located at the origin. The Z-axis is vertical downward, and the X-axis is aligned with the ground projection of the original line-of-sight vector. The missile body axes are fixed in the missile with the X-axis aligned longitudinally and the Y- and Z-axes aligned with the control surfaces. Since the control surface orientation is nominally at 45-degree angles with the horizontal and vertical, these axes are also rotated in this manner. The autopilot axes are also fixed in the missile body with the X-axis oriented longitudinally but with the Y- and Z-axes rotated 45 degrees from the missile body axes. The seeker coordinates are fixed to the seeker head and are aligned with the autopilot axes when the seeker gimbal angles are set to zero.

(U) A fifth set of coordinate axes is used in the aerodynamics calculations. These are the maneuver axes which are obtained by rotating the missile body axes about the X-axis through the aerodynamic roll angle. In addition, a sixth coordinate set is also used for miss distance calculations. This miss distance coordinate set may be obtained from the inertial coordinate set simply by a rotation about the Y-axis which aligns the X-axis with the initial line of sight. When miss distance is measured in this coordinate set, it is taken as the missile-to-target distance at the point where the x-component of range reduces to zero.

(U) The coordinate sets described above are listed for convenience in Table I. Figure 4 depicts the Euler angle relationships among the various sets by means of piograms (or resolver chains). With the exception of earth-fixed coordinates, these coordinate systems are also shown graphically in Figure 5.

2.3.2 Main Program

(U) Within the simulation, each subroutine or module deals, for the most part, with only a single set of coordinates. Transformations between these coordinates are therefore performed largely in the main or call

TABLE I. SIMULATION COORDINATE SYSTEMS

Coordinate System	Description
Inertial (Earth)	Fixed in earth with the origin at initial missile location. X-axis is horizontal and aligned with ground projection of initial line of sight and positive in direction toward target. Z-axis is vertical and positive downward, Y-axis horizontal and positive in the sense to complete a right-handed system.
Miss Distance	Fixed in earth with X-axis aligned with original line of sight and positive in direction toward target. This coordinate set is obtained by a rotation of the earth coordinates about the Y-axis.
Autopilot	Fixed in the missile body with Y- and Z-axes at 45 degrees to the planes of the control surfaces, and with the X-axis in the longitudinal axis of the missile, positive in the direction of flight. This set is related to the inertial system by three Euler rotations in the following sequence: Earth-Yaw-Roll-Pitch-Autopilot The positive sense of these rotations is the same as the positive sense of the axes about which the rotations take place.
Missile	Fixed in the missile body with the Y- and Z-axes in the planes of the control surfaces. This coordinate set is obtained by a rotation of the autopilot axes through 45 degrees about the positive X-axis.
Seeker	Fixed to the seeker head with the X-axis aligned with the boresight. This set is related to the autopilot system by two gimbal rotations in the following sequence: Autopilot-Elevation-Azimuth-Seeker The gimbal rotations, elevation, and azimuth are taken about the nominal autopilot Y- and Z-axes, respectively, with the positive sense of rotation being the same as that of the axis about which it takes place.

TABLE I. SIMULATION COORDINATE SYSTEMS (CONCLUDED)

Coordinate System	Description
Maneuver	This coordinate system is related to the missile coordinate system but is not fixed in the missile body. The X-axis is aligned with that of the missile set, but the Z-axis is selected so that the missile velocity vector lies in the XZ-plane. The direction of the lateral component of missile velocity fixes the positive direction of the Z-plane. The angle through which the missile axes must be rotated about the negative X-axis to coincide with the maneuver axes is called the aerodynamic roll angle, ϕ_a. When no lateral component of velocity exists, ϕ_a is taken to be 45 degrees.
NOTE: All systems are in right-handed rectangular cartesian coordinates.	

program which serves primarily to direct signal flows among the four functional subroutines and to permit the input and output of data.

(U) A FORTRAN listing of the call program appears in Table II. The flow chart and block diagram for this program appear in Figures 6 and 7, respectively. Table III is a glossary of the terms used in this program. This includes the dimensions and coordinate systems referred to as well as the subscripted variable or constant number used to identify the term.

2.3.3 <u>Initial Condition Subroutine (Setic)</u>

(U) The primary purpose of this subroutine is to accept the data which specifies the missile conditions at the time of launch and to convert this data into initial conditions useable by the simulation. Since the values of certain system parameters are also subject to change over a series of simulated trajectories, this subroutine also provides for a common area of data input shared by these parameters and the initial conditions. This common area is the T-array provided by the SADSAM system. The inputs and outputs of this subroutine are shown in Tables IV and V, respectively. The physical relationships between the various input quantities are indicated in Figures 8 through 10. The definition of the output quantities is the same as that of Table III.

TABLE II. MAIN PROGRAM FORTRAN LISTING

```
$     FORTRAN DECK
CCALL        MAVERICK SIMULATION                                             CALL0010
      COMMON /SSAM/ IEND,ND,TNEXT,VMIN,STPMX,S12345,SUM222
     1,CETA,SETA,CNU,SNU,IMAX,NZ,INV(50),TITLE(250),DELIO,RTITLE(9)
     2,IFGEN,IMFGEN,MFGEN2,IFG2N
      COMMON /SSAM1/ READ,DELT,AUTOT,TIME
      COMMON /SSAM2/ V  (250),T  (250),C  (250)
      COMMON /TRAKER/ COUNT,TR,N1
     1          ,GFFX,GFFY

      EQUIVALENCE                                                            CALL0080
     1 (V( 1),ALT   ),(V(2 ),DAC   ),(V( 3),DPC   ),(V( 4),DYC   ),          CALL0090
     2 (V( 5),DA    ),(V( 6),DP    ),(V( 7),DY    ),(V( 8),VXM   ),          CALL0100
     3 (V( 9),VYM   ),(V(10),VZM   ),(V(11),WX    ),(V(12),WY    ),          CALL0110
     4 (V(13),WZ    ),(V(14),AXM   ),(V(15),AYM   ),(V(16),AZM   ),          CALL0120
     5 (V(17),AZCMD ),(V(18),AYCMD ),(V(19),YAW   ),(V(20),ROLL  ),          CALL0130
     6 (V(21),PITCH ),(V(22),RXS   ),(V(23),RYS   ),(V(24),RZS   ),          CALL0140
     7 (V(25),TEAP  ),(V(26),TEAY  ),(V(27),SEGA  ),(V(28),SAGA  ),          CALL0150
     8 (V(29),RX    ),(V(30),RY    ),(V(31),EP1   ),(V(32),EP2   ),          CALL0160
     9 (V(33),ALPHA ),(V(34),ALPHAP),(V(35),ALPHAY),(V(36),VXE   )           CALL0170
      EQUIVALENCE                                                            CALL0180
     1 (V(37),VYE   ),(V(38),VZE   ),(V(39),Q     ),(V(40),VM    ),          CALL0190
     2 (V(41),AM    ),(V(42),ACP   ),(V(43),ACY   ),(V(44),DWX   ),          CALL0200
     3 (V(45),DWY   ),(V(46),DWZ   ),(V(47),DDAC  ),(V(48),DDPC  ),          CALL0210
     5 (V(49),DDYC  ),(V(50),TSMISS),(V(51),YSMISS),(V(52),ZSMISS),          CALL0220
     6 (V(53),WXP   ),(V(54),WYP   ),(V(55),WZP   ),(V(56),DWXP  ),          CALL0230
     7 (V(57),DWYP  ),(V(58),DWZP  ),(V(59),AXP   ),(V(60),AYP   ),          CALL0240
     8 (V(61),AZP   ),(V(62),VXP   ),(V(63),VYP   ),(V(64),VZP   )           CALL0250
     X,(V(67),RXM   ),(V(68),RYM   ),(V(69),RZM   )                          CALL0260
      EQUIVALENCE                                                            CALL0270
     1(V(66),TOTMIS),(V(70),EMJ    ),(V(71),EMK    ),                        CALL0280
     1 (V(72),AXE   ),(V(73),AYE   ),(V(74),AZE   ),(V(75),ABRH  ),          CALL0290
     2 (V(76),ABRV  ),(V(77),HORBT ),(V(78),VERIBT),(V(79),SIGMAE),          CALL0300
     3 (V(80),XISURF),(V(81),XLOS  ),(V(82),YLOS  ),(V(83),ZLOS  ),          CALL0310
     4 (V(85),DE    ),(V(86),DEXS)
      EQUIVALENCE
     1 (V(110),WWD  ),(V(118),TEYD ),(V(119),TEPD ),(V(120),UWD  ),
     2 (V(121),ETAD ),(V(122),WXD  ),(V(123),WYD  ),(V(124),WZD  ),
     3 (V(125),XLOSD),(V(126),YLOSD),(V(127),ZLOSD),(V(128),ANT  ),
     4 (V(129),YAWD ),(V(130),ROLLD),(V(131),PITD ),(V(132),DED  ),
     5 (V(133),DEXSD), (V(134),DB), (V(135),DE1),(V(137),FLAG)
      EQUIVALENCE
     1(C(109),XK1),     (C(110),XK2),     (C(111),PK1),     (C(112),TAU1),
     2(C(113),TAU2),    (C(114),TB),      (C(115),TC)
      EQUIVALENCE
     1(C(116),W3S),     (C(117),K2T),        (C(118),DUMP),(C(156),PC),
     2 (C(159),DEV(1))
C                                                                            CALL0320
C                                                                            CALL0330
C     THIS MODEL HAS THE MISSILE FLYING AT A 45 DEG. ROLL ANGLE              CALL0340
      SUM222=0.0                                                             CALL0350
      READ=1.0                                                               CALL0360
    6 COUNT=0.0                                                              CALL0370
      CALL LOAD                                                              CALL0380
      TBX=TB                                                                 CALL0381
      TCX=TC                                                                 CALL0382
      DEL11=TC-TB
      C12=-1.
      B17=0.
```

TABLE II. MAIN PROGRAM FORTRAN LISTING (CONTINUED)

```
      C1=0.
      B1=0.
C     C(1)   THROUGH C(12)   ARE RESERVED FOR THE MAIN PROGRAM          CALL0390
C     C(13)  THROUGH C(42)   ARE RESERVED FOR THE SEEKER SUBROUTINE     CALL0400
C     C(43)  THROUGH C(72)   ARE RESERVED FOR THE PILO   SUBROUTINE     CALL0410
C     C(73)  THROUGH C(96)   ARE RESERVED FOR THE AERO   SUBROUTINE     CALL0420
C     C(97) THROUGH C(102) ARE RESERVED FOR THE FLIPPER SUBROUTINE      CALL0430
C     C(109)   THROUGH C(120)  ARE RESERVED FOR THE SEEKER SUBROUTINE
C     C(103) - C(108) ARE RESERVED FOR AIM POINT WANDER ROUTINE         CALL0440
C     C(198)-C(250) RESERVED FOR BMAX DATA
C     C(1)=AUTOPILOT G BIAS                                             CALL0450
C     C(2)=AUTOPILOT ACTIVATION DELAY IN SECONDS                        CALL0460
C     C(3)= BLIND RANGE PITCH                                           CALL0470
C     C(4) = C(4)*D/DT(AYCMD) =GATE ANGLE ERROR                         CALL0480
C     C(5) = BLIND RANGE FILTER TIME CONSTANT. SET TO 0.0 TO EXCLUDE BRFCALL0490
C     C(6) = ANGLE RESTORATION GAIN                                     CALL0500
C     C(7) = REFERENCE RESTORATION ANGLE                                CALL0510
C     C(8) = TIME CONSTANT ANGLE RESTORATION FILTER                     CALL0520
C     C(9) = BLIND RANGE YAW                                            CALL0530
C     V(118)TO V(133) SPECIAL PRINT OUT VARIABLES
      CALL SETIC                                                        CALL0540
      RTOD=57.2957795
  110 I=1
   20 COUNT=COUNT+1.0                                                   CALL0550
      IF (COUNT.GT.2.)   GO TO 304
      N1=1
      TR=0.
      C1Z=C1
      GO TO 330
  304 T1=TIME+DELT
      C1=AINT(T1/TC)
      B1=AINT((T1+DELT1)/TC)
      IF (C1.EQ.C1Z)  GO TO 310
  305 N1=1
      TR=TC
      C1Z=C1
      GO TO 330
  310 IF (B1.EQ.B1Z)  GO TO 320
      N1=0
      TR=TB
      B1Z=B1
      GO TO 330
  320 N1=-1
      TR=AMOD(T1,TC)
  330 CONTINUE
C     ANGLE RESTORATION BIAS                                            CALL0560
      IF (TIME.GT.C(2)) CALL ARB                                        CALL0570
C                                                                       CALL0580
C     BLIND RANGE FILTER                                                CALL0590
      IF(FLAG.EQ.1.)CALLBRF
      IF (C(5).GT.0.0) CALL BRF                                         CALL0610
C                                                                       CALL0600
   50 CALL MAERO                                                        CALL0620
  120 I=2
```

TABLE II. MAIN PROGRAM FORTRAN LISTING (CONCLUDED)

```
      CALL MPILOT                                                      CALL0630
  130 I=3
      CALL MFLIP                                                       CALL0640
  140 I=4
      CALL R45R(WX,WY,WZ,WXP,WYP,WZP)                                  CALL0650
      CALL EULANG(WXP,WYP,WZP,YAW,ROLL,PITCH)                          CALL0660
      CALL R45R(DWX,DWY,DWZ,DWXP,DWYP,DWZP)                            CALL0670
      CALL R45R(AXM,AYM,AZM,AXP,AYP,AZP)                               CALL0680
      CALL R45R(VXM,VYM,VZM,VXP,VYP,VZP)                               CALL0690
      CALL EULTRN(1,1,VXE,VYE,VZE,VXP,VYP,VZP,YAW,ROLL,PITCH)          CALL0700
      CALL MSEEK                                                       CALL0710
  150 I=5
      CALL SEKTR (0,-1,RXM,RYM,RZM,RXS,RYS,RZS,SEGA,SAGA)              CALL0720
  160 I=6
      CALL EULTRN (0,1,RX,RY,ALT,RXM,RYM,RZM,YAW,ROLL,PITCH)           CALL0730
  170 I=7
      CALL EULTRN(0,1,AXE,AYE,AZE,AXP,AYP,AZP,YAW,ROLL,PITCH)          CALL0740
      RSQ=V(29)**2+V(30)**2+V(1)**2                                    CALL0770
      XLOS=(V(30)*V(38)-V(1)*V(37))/RSQ                                CALL0780
      YLOS=(V(1)*V(36)-V(29)*V(38))/RSQ                                CALL0790
      ZLOS=(V(29)*V(37)-V(30)*V(36))/RSQ                               CALL0800
      XLOSD=XLOS*RTOD
      YLOSD=YLOS*RTOD
      ZLOSD=ZLOS*RTOD
      WXD=WX*RTOD
      WYD=WY*RTOD
      WZD=WZ*RTOD
      TEYD=TEAY*RTOD
      TEPD= TEAP*RTOD
      UND=SEGA*RTOD
      ETAD=SAGA*RTOD
      YAWD=YAW*RTOD
      ROLLD=ROLL*RTOD
      PITD=PITCH*RTOD
      DED=DE*RTOD
      DEXSD=DEXS*RTOD
      ANT=SQRT((AYM)**2+(AZM)**2)
      V(65)=S12345                                                     CALL0810
C     IF (TIME.LT.TBX)  GO TO 60                                       CALL082X
C     TBX=TBX+TC                                                       CALL0821
C  60 CALL TTEST(TBX)                                                  CALL0822
      IF (TIME.LT.TCX)  GO TO 70
      TCX=TCX+TC
   70 CALL TTEST(TCX)
      CALL PRINTS(-V(22))
      CALL BMAX
      IF (IEND) 20,1000,1000                                           CALL0840
 1000 WRITE (6,1001) COUNT                                             CALL0850
 1001 FORMAT (1H1,28H TOTAL NUMBER OF ITERATIONS=,1PE15.7)             CALL0860
      GO TO 6                                                          CALL0920
      END                                                              CALL0930
```

(U) A listing of this subroutine is shown in Table VI, and a flow chart appears in Figure 11.

(U) Several points must be clarified regarding two of the inputs to this subroutine. The effective tracker time constant T(13) is used to establish initial tracking error angles only; it is not used thereafter. The assumption is made that, at time of launch, the tracking loop has achieved steady state, so that tracking error is proportional to the product of line-of-sight rate and tracker time constant. This initial error may be eliminated by setting this input to zero. In this case, the performance of the simulation would be otherwise unchanged.

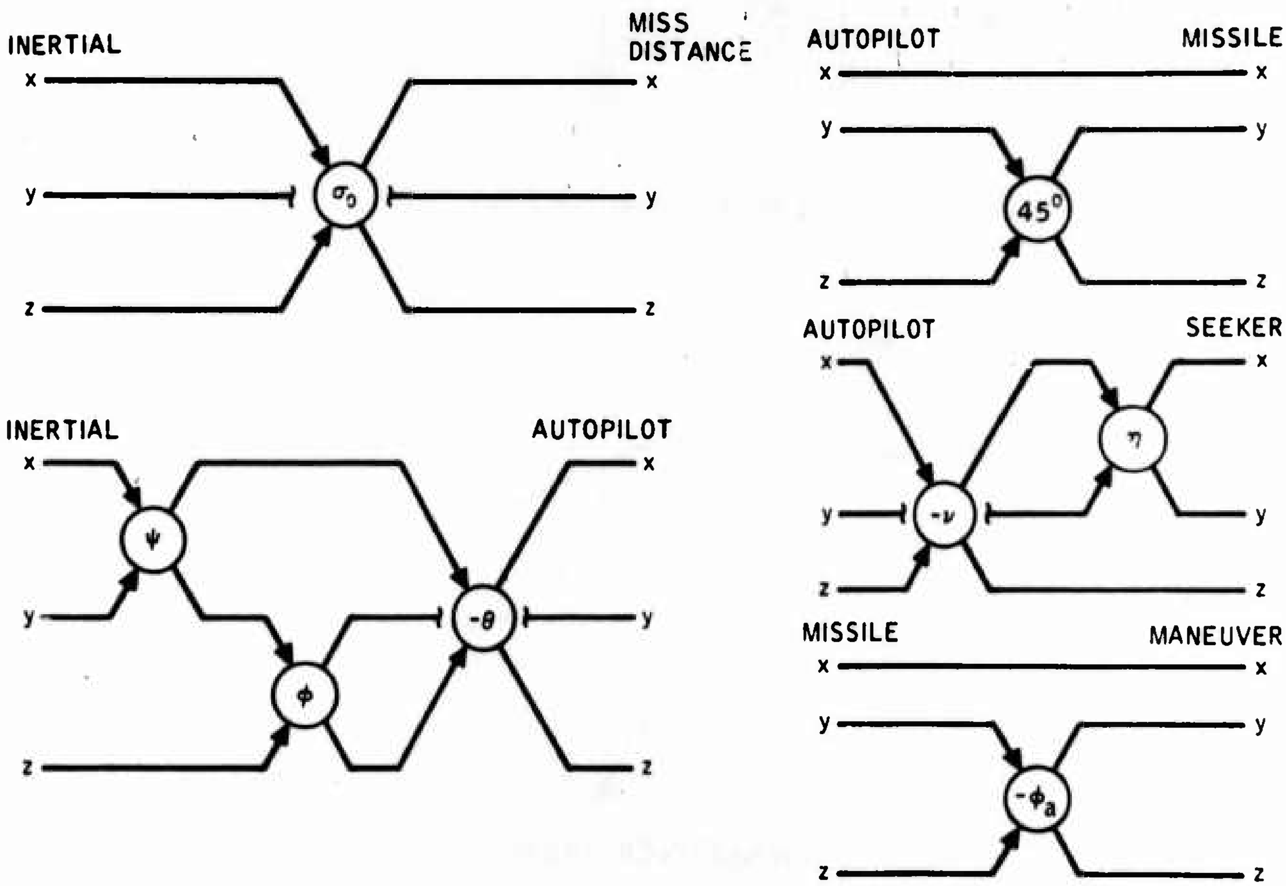

Figure 4. Piograms Showing Euler Angle Relationships Between Coordinate Sets

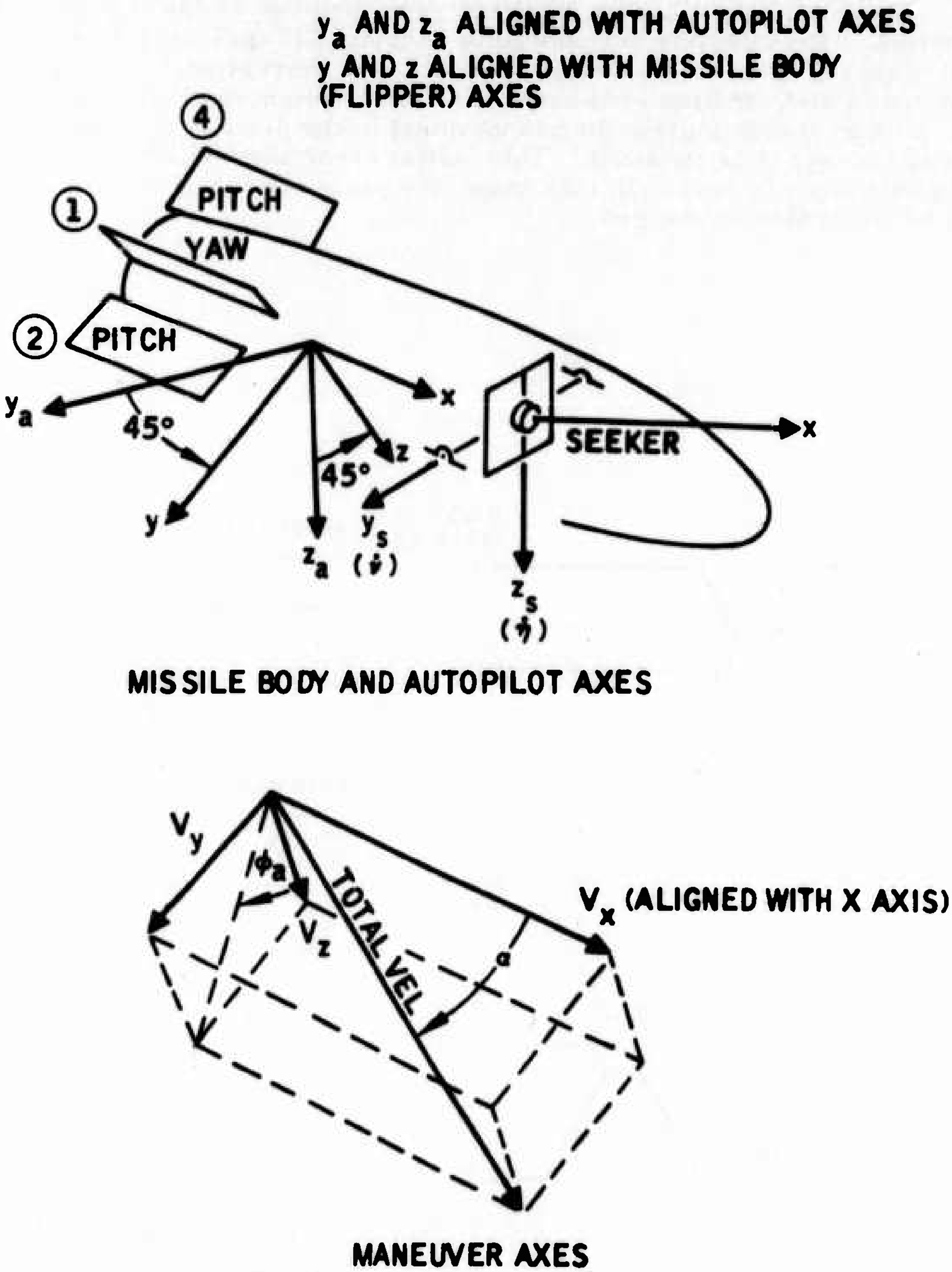

Figure 5. Simulation Coordinate System

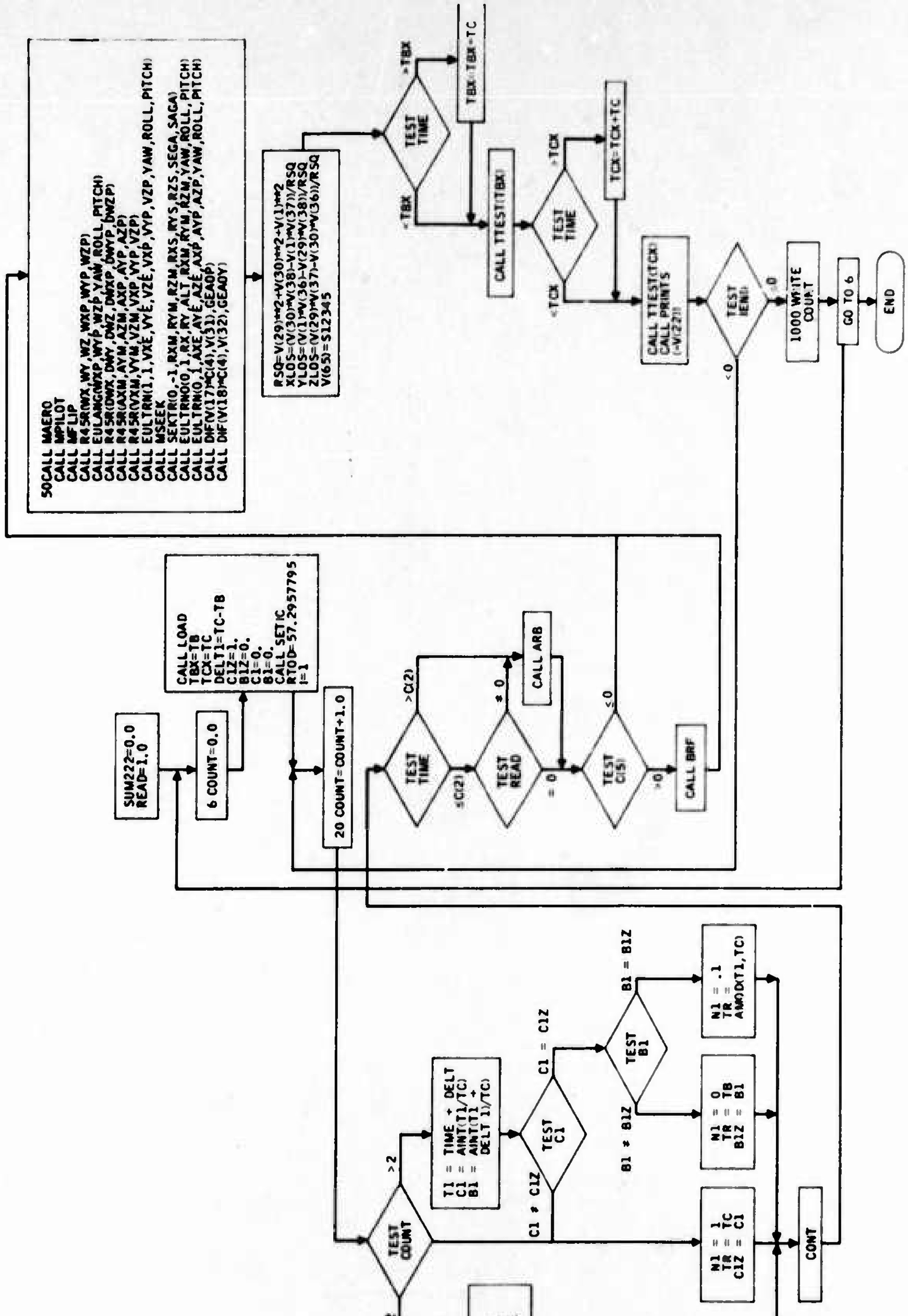

Figure 6. Call Program Flow Chart

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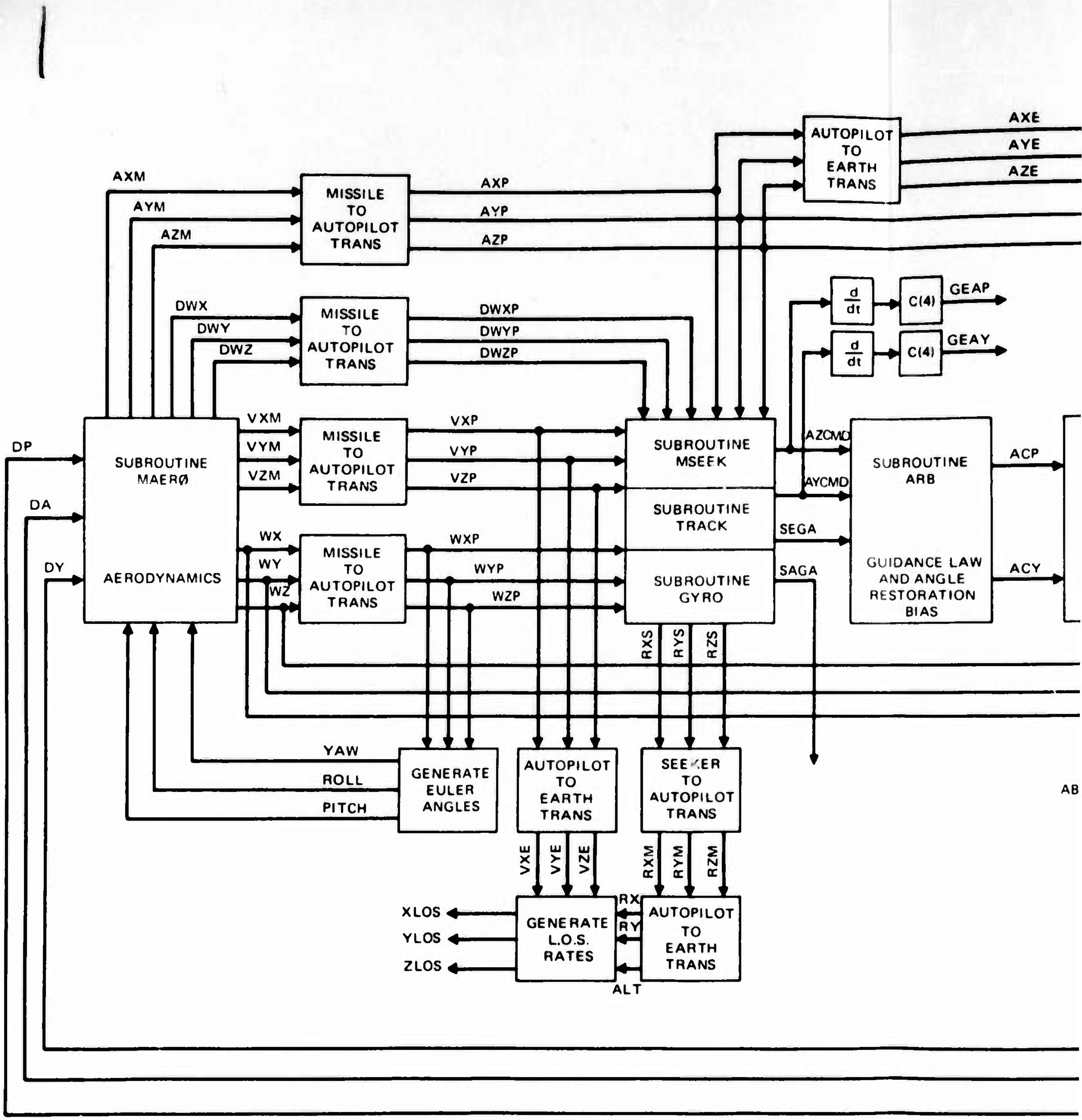

AXE
AYE
AZE
AUTOPILOT TO EARTH TRANS
AXM
AYM
AZM
MISSILE TO AUTOPILOT TRANS
AXP
AYP
AZP
d/dt
C(4)
GEAP
GEAY
DWX
DWY
DWZ
MISSILE TO AUTOPILOT TRANS
DWXP
DWYP
DWZP
DP
DA
DY
SUBROUTINE MAERØ
AERODYNAMICS
VXM
VYM
VZM
MISSILE TO AUTOPILOT TRANS
VXP
VYP
VZP
SUBROUTINE MSEEK
SUBROUTINE TRACK
SUBROUTINE GYRO
AZCMD
AYCMD
SEGA
SAGA
SUBROUTINE ARB
GUIDANCE LAW AND ANGLE RESTORATION BIAS
ACP
ACY
WX
WY
WZ
MISSILE TO AUTOPILOT TRANS
WXP
WYP
WZP
RXS
RYS
RZS
YAW
ROLL
PITCH
GENERATE EULER ANGLES
AUTOPILOT TO EARTH TRANS
SEEKER TO AUTOPILOT TRANS
AB
VXE
VYE
VZE
RXM
RYM
RZM
XLOS
YLOS
ZLOS
GENERATE L.O.S. RATES
RX
RY
ALT
AUTOPILOT TO EARTH TRANS

2

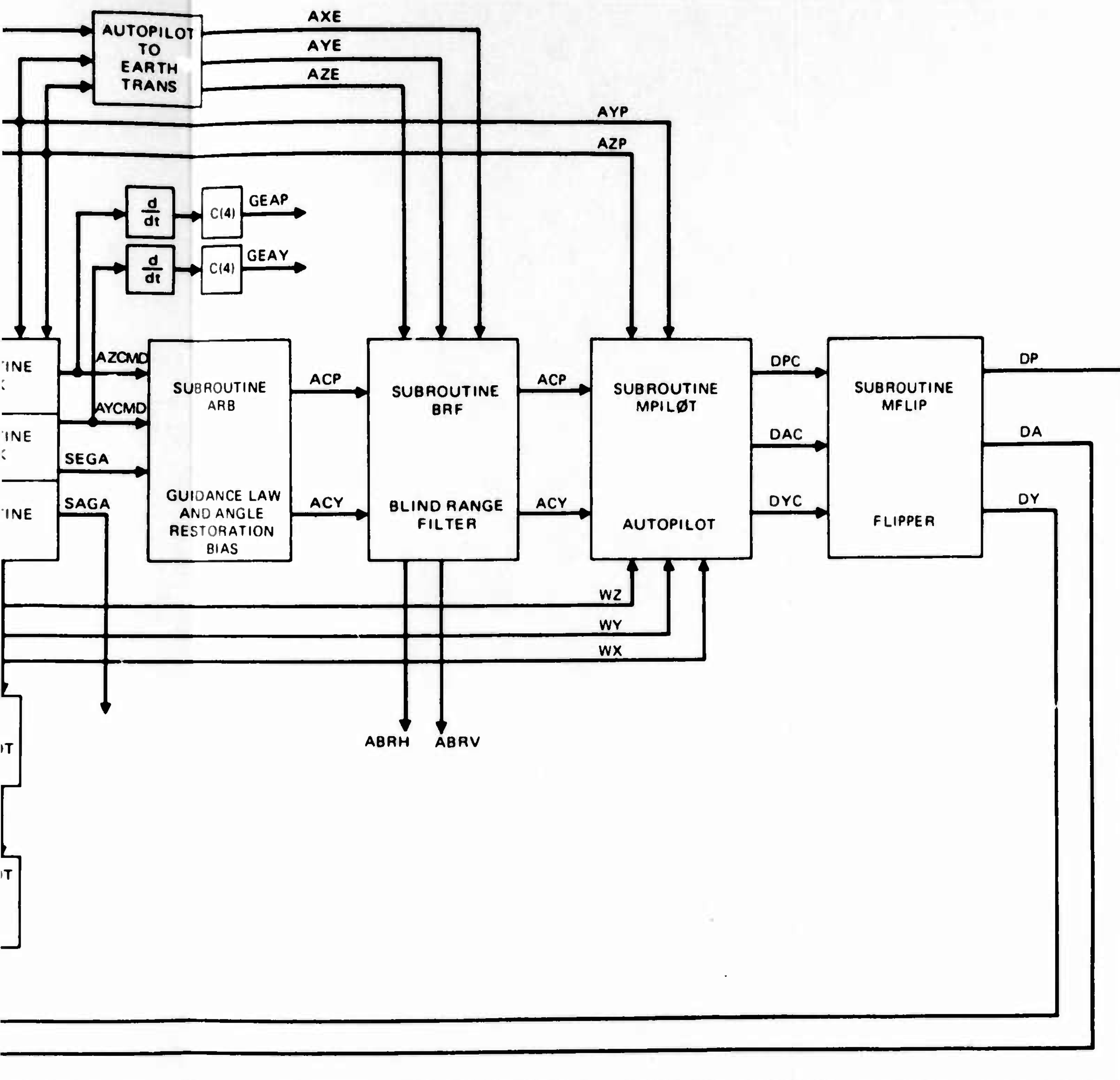

Figure 7. Call Program Flow Diagram

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TABLE III. CALL PROGRAM GLOSSARY, V ARRAY

Name	Quantity	Units	Coordinate System
V(1)	hm, Missile altitude above ground	ft	Inertial
V(2)	δ_{ac}, Aileron deflection command	deg	Missile
V(3)	δ_{pc}, Pitch deflection command	deg	Missile
V(4)	δ_{yc}, Yaw deflection command	deg	Missile
V(5)	δ_a, Aileron deflection	deg	Missile
V(6)	δ_p, Pitch deflection	deg	Missile
V(7)	δ_y, Yaw deflection	deg	Missile
V(8)	V_x, Missile velocity X-axis	ft/sec	Missile
V(9)	V_y, Missile velocity Y-axis	ft/sec	Missile
V(10)	V_z, Missile velocity Z-axis	ft/sec	Missile
V(11)	ω_x, Angular velocity	rad/sec	Missile
V(12)	ω_y, Angular velocity	rad/sec	Missile
V(13)	ω_z, Angular velocity	rad/sec	Missile
V(14)	A_x, Propulsion and aerodynamic acceleration	g	Missile
V(15)	A_y, Propulsion and aerodynamic acceleration	g	Missile
V(16)	A_z, Propulsion and aerodynamic acceleration	g	Missile
V(17)	A_{zc}, Elevation maneuver command	g	Autopilot
V(18)	A_{yc}, Azimuth maneuver command	g	Autopilot
V(19)	ψ, Euler yaw angle	rad	
V(20)	ϕ, Euler roll angle	rad	
V(21)	θ, Euler pitch angle	rad	
V(22)	R_x, Seeker boresight range	ft	Seeker
V(23)	R_y, Seeker lateral range	ft	Seeker
V(24)	R_z, Seeker normal range	ft	Seeker
V(25)	ϵ_z, Tracking error angle, pitch	rad	Seeker
V(26)	ϵ_y, Tracking error angle, yaw	rad	Seeker
V(27)	ν, Seeker elevation gimbal angle	rad	
V(28)	η, Seeker azimuth gimbal angle	rad	

TABLE III. CALL PROGRAM GLOSSARY, V ARRAY (CONTINUED)

Name	Quantity	Units	Coordinate System
V(29)	R_i, Horizontal longitudinal range component	ft	Inertial
V(30)	R_j, Horizontal lateral range component	ft	Inertial
V(31)	ϵ_{gz}, Gate error angle, pitch	rad	Seeker
V(32)	ϵ_{gy}, Gate error angle, yaw	rad	Seeker
V(33)	α, Total miss angle of attack	deg	Missile
V(34)	α_p, Missile pitch angle of attack	deg	Missile
V(35)	α_y, Missile yaw angle of attack	deg	Missile
V(36)	V_i, Horizontal longitudinal velocity component	ft/sec	Inertial
V(37)	V_j, Horizontal lateral velocity component	ft/sec	Inertial
V(38)	V_k, Vertical velocity component	ft/sec	Inertial
V(39)	q, Dynamic pressure	lb/ft^2	
V(40)	Total missile velocity	ft/sec	
V(41)	Missile Mach number		
V(42)	a_{cp}, Acceleration command pitch	g	Autopilot
V(43)	a_{cy}, Acceleration command yaw	g	Autopilot
V(44)	$\dot{\omega}_x$ Scalar components of missile angular acceleration in missile axes	rad/sec^2	Missile
V(45)	$\dot{\omega}_y$ Scalar components of missile angular acceleration in missile axes	rad/sec^2	Missile
V(46)	$\dot{\omega}_z$ Scalar components of missile angular acceleration in missile axes	rad/sec^2	Missile
V(47)	$\dot{\delta}_{ac}$, Aileron command rate	deg/sec	Missile
V(48)	$\dot{\delta}_{pc}$, Elevator command rate	deg/sec	Missile
V(49)	$\dot{\delta}_{yc}$, Rudder command rate	deg/sec	Missile
V(50)	Closest approach at end of flight	ft	
V(51)	Range component in Y seeker axis	ft	Seeker
V(52)	Range component in Z seeker axis	ft	Seeker
V(53)	ω'_x Missile body rates in autopilot axes	rad/sec	Autopilot
V(54)	ω'_y Missile body rates in autopilot axes	rad/sec	Autopilot
V(55)	ω'_z Missile body rates in autopilot axes	rad/sec	Autopilot

TABLE III. CALL PROGRAM GLOSSARY, V ARRAY (CONTINUED)

Name	Quantity	Units	Coordinate System
V(56)	ω'_x Scalar components of missile angular acceleration in autopilot axes	rad/sec^2	Autopilot
V(57)	ω'_y		
V(58)	ω'_z		
V(59)	A'_x Propulsive and aerodynamic acceleration components in autopilot axes	g	Autopilot
V(60)	A'_y		
V(61)	A'_z		
V(62)	V'_x Missile velocity components in autopilot axes	ft/sec	Autopilot
V(63)	V'_y		
V(64)	V'_z		
V(65)	Special test variable - used as system diagnostic		
V(66)	Total miss distance	ft	Miss Distance
V(67)	x component of range	ft	Autopilot
V(68)	y component of range	ft	Autopilot
V(69)	z component of range	ft	Autopilot
V(70)	y component of miss	ft	Miss Distance
V(71)	z component of miss	ft	Miss Distance
V(72)	x component of acceleration	g	Inertial
V(73)	y component of acceleration	g	Inertial
V(74)	z component of acceleration	g	Inertial
V(75)	y component of acceleration at blind range	g	Miss Distance
V(76)	z component of acceleration at blind range	g	Miss Distance
V(77)	Blind time in yaw channel	sec	
V(78)	Blind time in pitch channel	sec	
V(79)	Final line of sight angle (vertical)	rad	Inertial
V(80)	Final heading angle (horizontal)	rad	Inertial
V(81)	x component, LOS rate	rad/sec	Inertial
V(82)	y component, LOS rate	rad/sec	Inertial
V(83)	z component, LOS rate	rad/sec	Inertial
V(84)	Λ, Guidance gain		

TABLE III. CALL PROGRAM GLOSSARY, V ARRAY (CONTINUED)

Name	Quantity	Units	Coordinate System
V(85)	DE Total yaw precession rate		
V(86)	DEXS Total pitch precession rate		
V(87)	E Yaw gyro inertial angle		
V(88)	C1 Yaw look angle (indicated)		
V(90)	G1 Forcing function cross-coupled equation 1		
V(91)	DG1 Derivative forcing function cross-coupled equation 1		
V(92)	G2 Forcing function cross-coupled equation 2		
V(93)	DG2 Derivative forcing function cross-coupled equation 2		
V(94)	G1N Integral forcing function cross-coupled equation 1		
V(95)	G2N Integral forcing function cross-coupled equation 2		
V(96)	FFE Forcing function yaw axis		
V(97)	DFE Derivative forcing function yaw axis		
V(98)	FEXS Forcing function pitch axis		
V(99)	DFEXS Derivative forcing function pitch axis		
V(100)			
V(101)			
V(102)			
V(103)			
V(104)			
V(105)	NOT USED		
V(106)			
V(107)			
V(108)			
V(109)			
V(110)			

TABLE III. CALL PROGRAM GLOSSARY, V ARRAY (CONCLUDED)

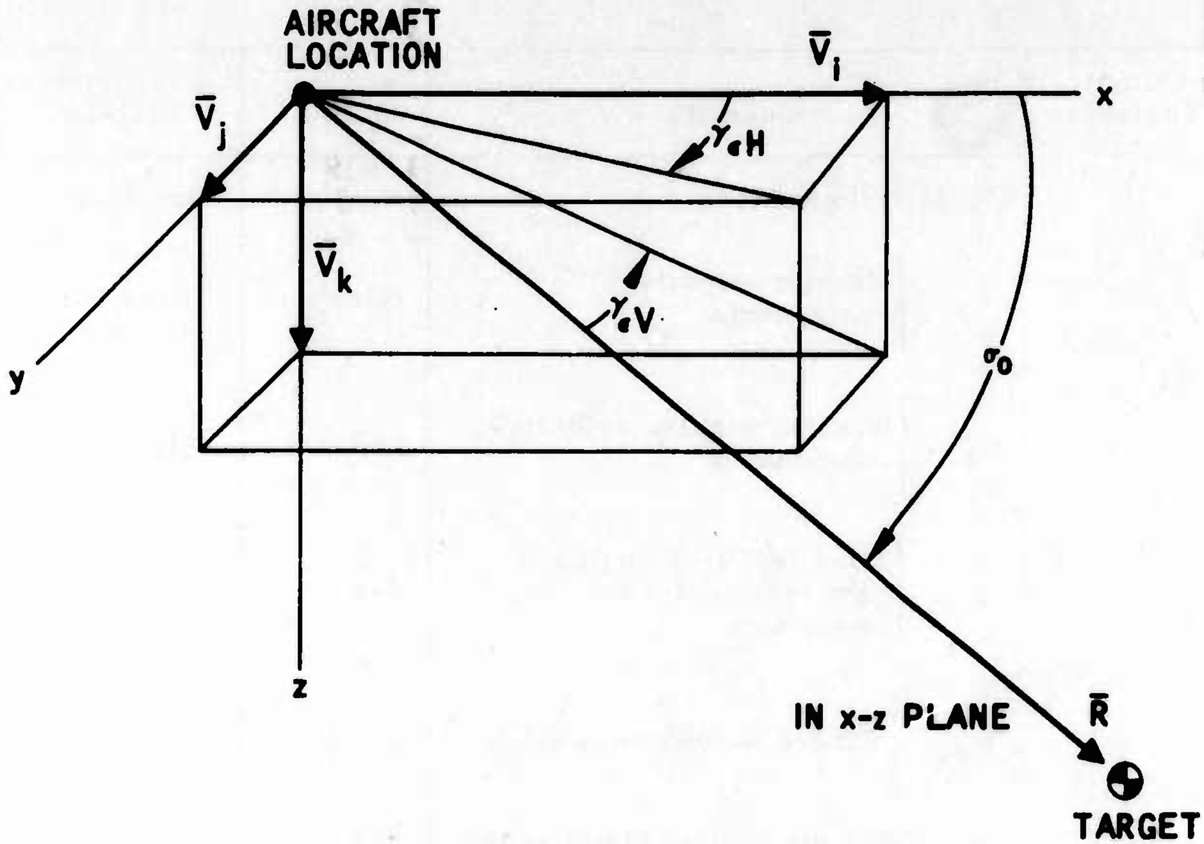
Name	Quantity	Units	Coordinate System
V(111)	Sum1 - Tracker sampler bias	sec	
V(112)	TEAYD Tracker error yaw · RKAMG	deg	
V(113)	TEAPD Tracker error pitch · RKAMG	deg	
V(114)	TEAYS - Tracker ZØH output Signal, Yaw	deg	
V(115)	TEAPS - Tracker ZØH output Signal, Pitch	deg/sec	
V(116)	VSYP - Tracker output signal Pitch	deg/sec	
V(117)	VSPP - Tracker output signal yaw	deg/sec	
V(118)	TEYD - Tracking error - yaw	deg	
V(119)	TEPD - Tracking error - pitch	deg	
V(120)	UND Seeker elevation	deg	
V(121)	ETAD Seeker azimuth	deg	
V(122)	WXD		
V(123)	WYD Missile angular velocity	deg	
V(124)	WZD		
V(125)	XLOSD		
V(126)	YLOSD LOS Rate, Inertial	deg/sec	
V(127)	ZLOSD		
V(128)	ANT (New)		
V(129)	ψ Yaw D		
V(130)	ϕ Roll D Error Angle	deg	
V(131)	θ Pitch		
V(132)	DED Total precession rate, yaw	deg/sec	
V(133)	DEXSD Total precession rate, pitch		

TABLE IV. INPUT TO SUBROUTINE SETIC

Input Location	Quantity	Units
T(1)	$\overline{R}$, Total range to target	ft
T(2)	V_o, Launch velocity	ft/sec
T(3)	σ_o, Line of sight angle	deg
T(4)	γ_{EV}, Heading error, vertical	deg
T(5)	γ_{EH}, Heading error, horizontal	deg
T(6)	ϕ'_a, Aircraft roll angle	deg
T(7)	A_{aL}, Aircraft normal acceleration	g
T(8)	A_{aY}, Aircraft lateral acceleration	g
T(9)	α_{po}, Aircraft angle of attack, trim	deg
T(10)	$\frac{\partial \alpha}{\partial A}$, Angle of attack, gain	deg/g
T(11)	ϕ_ℓ, Missile mounting angle, roll	deg
T(12)	θ_ℓ, Missile mounting angle, pitch	deg
T(13)	τ_a, Effective tracker time constant used to calculate initial tracking error angle	sec
T(14)	ω_x Missile body rates in autopilot axes	rad/sec
T(15)	ω_y Missile body rates in autopilot axes	rad/sec
T(16)	ω_z Missile body rates in autopilot axes	rad/sec
T(17)	R_{BH}, Blind range, horizontal	ft
T(18)	R_{BV}, Blind range, vertical	ft
T(19)	Steering bias, pitch	g
T(20)	Steering bias, yaw	g
T(21)	Roll rate bias	rad/sec

TABLE V. SUBROUTINE SETIC OUTPUT

Output Variable	Quantity	Units	Coordinate System
V(1)	h, Missile altitude	ft	Inertial
V(8)	V_x Missile velocity components	ft/sec	Missile
V(9)	V_y		
V(10)	V_z		
V(11)	ω_x Missile angular velocity components	rad/sec	Missile
V(12)	ω_y		
V(13)	ω_z		
V(19)	ψ Missile Euler angles in yaw, roll and pitch sequences	rad	
V(20)	ϕ		
V(21)	θ		
V(22)	R_{xs} Target range components	ft	Seeker
V(23)	R_{ys}		
V(24)	R_{zs}		
V(27)	ν, Seeker elevation gimbal angle	rad	
V(28)	η, Seeker azimuth gimbal angle	rad	
V(29)	R_i, Horizontal range component to target	ft	Inertial
V(67)	R_{xm} Target range components	ft	Autopilot
V(68)	R_{ym}		
V(69)	R_{zm}		

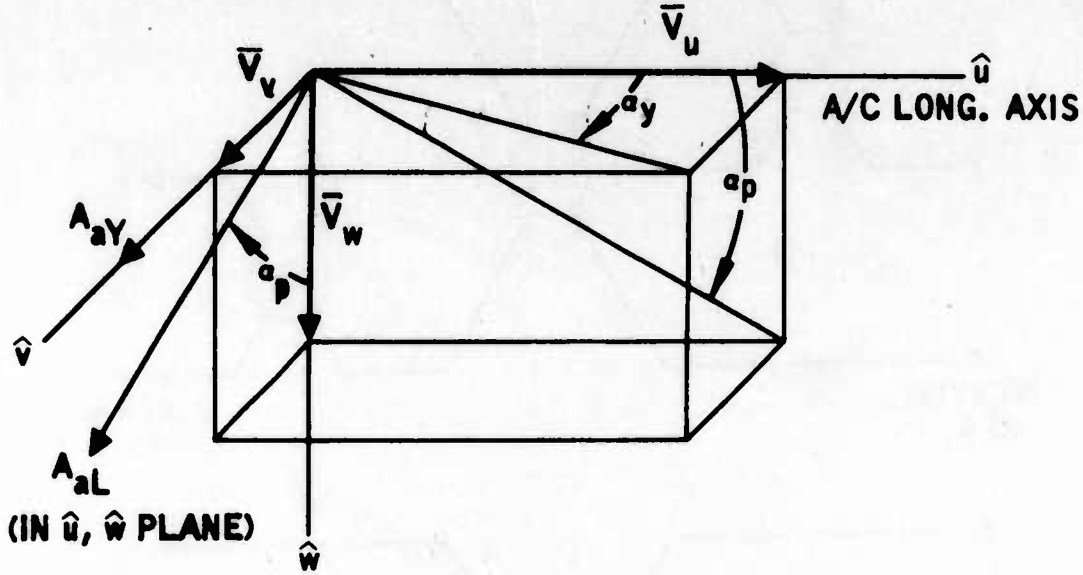


x, y, z INERTIAL COORDINATE AXES

$\bar{V}_i$, $\bar{V}_j$, $\bar{V}_k$ AIRCRAFT VELOCITY COMPONENTS

THE INERTIAL AXES ARE SELECTED SO THAT THE INITIAL RANGE VECTOR IS CONTAINED IN THE x-z PLANE

Figure 8. Launch Geometry in Inertial Coordinates



$\hat{u}, \hat{v}, \hat{w}$ AIRCRAFT COORDINATE AXES

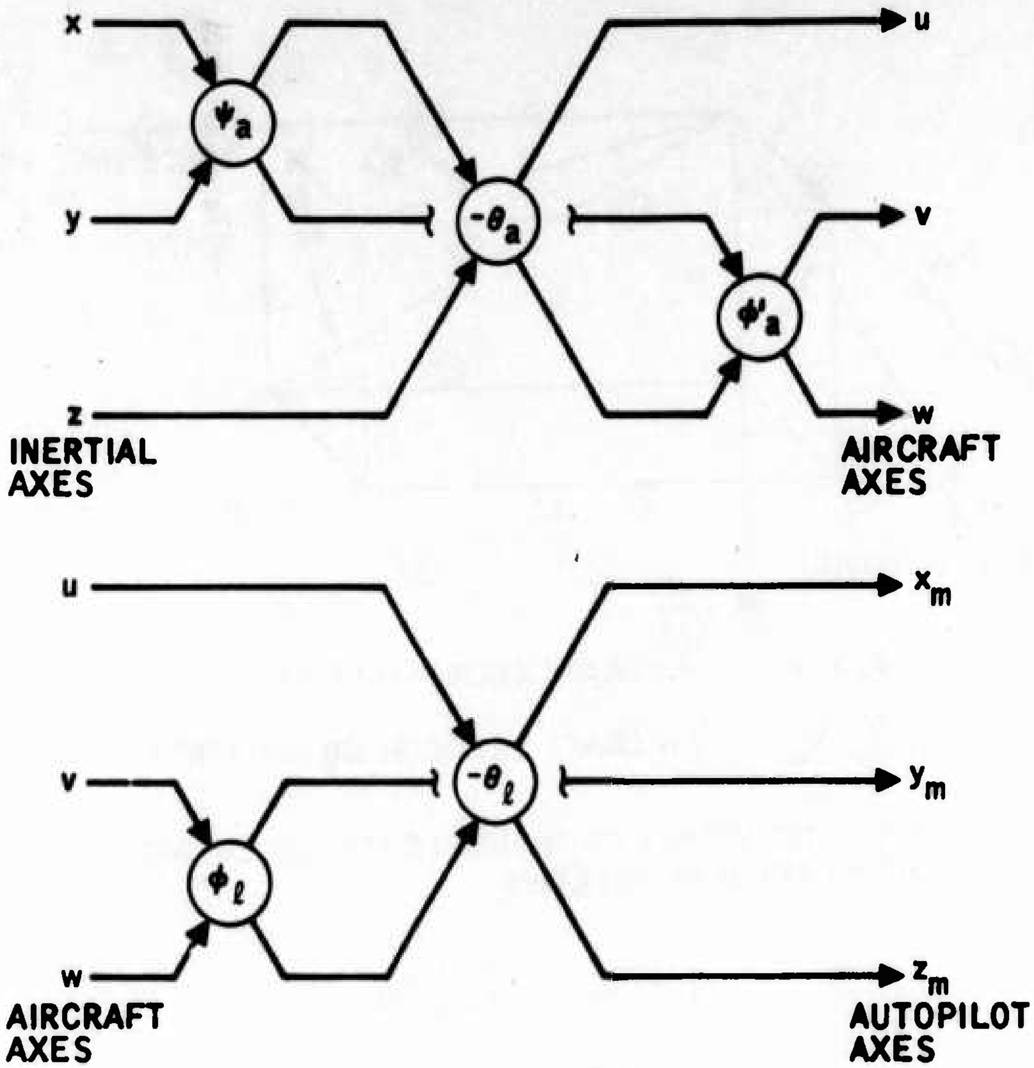
$\bar{V}_u, \bar{V}_v, \bar{V}_w$ AIRCRAFT VELOCITY COMPONENTS

ANGLE OF ATTACK COMPONENTS ARE CALCULATED WITHIN SETIC AS FOLLOWS:

$$\alpha_p = \alpha_{po} + \left(\frac{\partial \alpha}{\partial A}\right) A_{aL}$$

$$\alpha_y = \left(\frac{\partial \alpha}{\partial A}\right) A_{aY}$$

Figure 9. Launch Geometry in Aircraft Coordinates



ψ_a AND θ_a ARE COMPUTED WITHIN SETIC.
ALL OTHER ANGLES ARE PROVIDED AS INPUTS.

Figure 10. Euler Angle Relations Between Coordinate Axis Sets

TABLE VI. SUBROUTINE SETIC FORTRAN LISTING

```
$      FORTRAN DECK
CSETIC        SET INITIAL CONDITIONS  I                                  SETI0010
       SUBROUTINE SETIC                                                   SETI0020
       COMMON /SSAM2/ V  (250),T  (250),C  (250)
       EQUIVALENCE                                                        SETI0050
      1 (T( 1),RANGE ),(T( 2),VEL   ),(T( 3),SIGMA ),(T( 4),HEV   ),      SETI0060
      2 (T( 5),HEH   ),(T( 6),ACROLL),(T( 7),ACCEL ),(T( 8),ACCELY),      SETI0070
      3 (T( 9),ALPO  ),(T(10),DALDA ),(T(11),PHIL  ),(T(12),THETAL),      SETI0080
      4 (T(13),TAUA  ),(T(14),WX    ),(T(15),WY    ),(T(16),WZ    )       SETI0090
       DATA RTOD/57.29578/                                                SETI0100
       C(9)=T(17)                                                         SETI0110
       C(3)=T(18)                                                         SETI0120
       GAMV=(SIGMA-HEV)/RTOD                                              SETI0130
       TANGV=TAN(GAMV)                                                    SETI0140
       HEHRAD=HEH/RTOD                                                    SETI0150
       TANH=TAN(HEHRAD)                                                   SETI0160
C      VELOCITY COMPONENTS IN EARTH AXES                                  SETI0170
       VI=VEL/SQRT(1.0+TANGV**2+TANH**2)                                  SETI0180
       VJ=VI*TANH                                                         SETI0190
       VK=VI*TANGV                                                        SETI0200
       ALPHAP=(ALPO+DALDA*ACCEL)/RTOD                                     SETI0210
       ALPHAY=DALDA*ACCELY/RTOD                                           SETI0220
       TANAP=TAN(ALPHAP)                                                  SETI0230
       TANAY=TAN(ALPHAY)                                                  SETI0240
C      VELOCITY COMPONENTS IN A/C AXES                                    SETI0250
       VU=VEL/SQRT(1.0+TANAP**2+TANAY**2)                                 SETI0260
       VV=VU*TANAY                                                        SETI0270
       VW=VU*TANAP                                                        SETI0280
       APHI=ACROLL/RTOD                                                   SETI0290
       SPHI=SIN(APHI)                                                     SETI0300
       CPHI=COS(APHI)                                                     SETI0310
C      ESTABLISH A/C EULER ANGLES                                         SETI0320
       CON1=VV*SPHI+VW*CPHI                                               SETI0330
       CON2=SQRT(VU*VU+CON1*CON1)                                         SETI0340
       THETAA=ARSN(CON1/CON2)-ARSN(VK/CON2)                               SETI0350
       CON3=SQRT(VI*VI+VJ*VJ)                                             SETI0360
       PSIA=ARSN(VJ/CON3)-ARSN((VV*CPHI-VW*SPHI)/CON3)                    SETI0370
       SPSI=SIN(PSIA)                                                     SETI0380
       CPSI=COS(PSIA)                                                     SETI0390
       STHE=SIN(THETAA)                                                   SETI0400
       CTHE=COS(THETAA)                                                   SETI0410
       THETLR=THETAL/RTOD                                                 SETI0420
       STHL=SIN(THETLR)                                                   SETI0430
       CTHL=COS(THETLR)                                                   SETI0440
       PHILR=PHIL/RTOD                                                    SETI0450
       SPHL=SIN(PHILR)                                                    SETI0460
       CPHL=COS(PHILR)                                                    SETI0470
       A13=-STHE*CTHL+CTHE*SPHI*SPHL*STHL-CTHE*CPHI*CPHL*STHL             SETI0480
       A23= CTHE*SPHI*CPHL+CTHE*CPHI*SPHL                                 SETI0490
       A21= (CPSI*STHE*SPHI-SPSI*CPHI)*CPHL +(CPSI*STHE*CPHI+SPSI*SPHI)*  SETI0500
      1       SPHL                                                        SETI0510
       CON4=SQRT(1.0-A23*A23)                                             SETI0520
C      ESTABLISH MISSILE EULER ANGLES                                     SETI0530
       PHI=ARSN(A23)                                                      SETI0540
       THETA=ARSN(-A13/CON4)                                              SETI0550
       PSIPR=ARSN(-A21/CON4)                                              SETI0560
       SSIG=SIN(SIGMA/RTOD)                                               SETI0570
       CSIG=COS(SIGMA/RTOD)                                               SETI0580
C      RANGE COMPONENTS IN EARTH AXES                                     SETI0590
       RI=RANGE*CSIG                                                      SETI0600
```

TABLE VI. SUBROUTINE SETIC FORTRAN LISTING (CONCLUDED)

```
      RK=RANGE*SSIG                                                     SETI0610
C     ESTABLISH TRACKING ERROR VECTOR                                   SETI0620
      CON6=VK*CSIG-VI*SSIG                                              SETI0630
      EI=TAUA*CON6*SSIG                                                 SETI0640
      EJ= TAUA*VJ                                                       SETI0650
      EK=-TAUA*CON6*CSIG                                                SETI0660
      PI=RI-EI                                                          SETI0670
      PK=RK-EK                                                          SETI0680
C     ESTABLISH SEEKER GIMBAL ANGLES                                    SETI0690
      CALL EULTRN(1,-1,PI,EJ,PK,RX,RY,RZ,PSIPR,PHI,THETA)               SETI0700
C     VELOCITY COMPONENTS IN MISSILE AXES                               SETI0710
      CALL EULTRN(-1,-1,VI,VJ,VK,VX,VY,VZ,PSIPR,PHI,THETA)              SETI0720
C     RANGE COMPONENTS IN MISSILE AXES                                  SETI0730
      CALL EULTRN(-1,-1,RI,0.0,RK,RXM,RYM,RZM,PSIPR,PHI,THETA)          SETI0740
C     VELOCITY COMPONENTS IN AUTOPILOT AXES                             SETI0750
      CALL R45F(VX,VY,VZ,VXM,VYM,VZM)                                   SETI0760
      UN=ATAN2(-RZ,RX)                                                  SETI0770
      ETA=ATAN2(RY,SQRT(RX*RX+RZ*RZ))                                   SETI0780
C     RANGE COMPONENTS IN SEEKER AXES                                   SETI0790
      CALL SEKTR(1,1,RXM,RYM,RZM,RXS,RYS,RZS,UN,ETA)                    SETI0800
      V(8)=VXM                                                          SETI0810
      V(9)=VYM                                                          SETI0820
      V(10)=VZM                                                         SETI0830
      V(19)=PSIPR                                                       SETI0840
      V(20)=PHI                                                         SETI0850
      V(21)=THETA                                                       SETI0860
      V(27)=UN                                                          SETI0870
      V(28)=ETA                                                         SETI0880
      V(1)=RK                                                           SETI0890
      V(29)=RI                                                          SETI0900
      V(67)=RXM                                                         SETI0910
      V(68)=RYM                                                         SETI0920
      V(69)=RZM                                                         SETI0930
      V(22)=RXS                                                         SETI0940
      V(23)=RYS                                                         SETI0950
      V(24)=RZS                                                         SETI0960
      CALL R45F(WX,WY,WZ,V(11),V(12),V(13))                             SETI0970
      RETURN                                                            SETI0980
      END                                                               SETI0990
```

(U) Also, the 45-degree rotation of the missile axes relative to the mounting hooks is not contained in the input T(11), ϕ_{ℓ}. This angle will nominally be approximately zero or ±90 degrees depending upon whether the missile is mounted on the bottom or sides of the pylon.

2.3.4 Universal Seeker Subroutine

(U) Input to the Universal Seeker subroutine are the components of the missile linear velocity and acceleration components as well as the angular velocity and acceleration components, all in autopilot axes. This subroutine performs the coordinate transformations of these quantities to seeker axes and performs the appropriate integrations to yield seeker range components from which tracking error angles in the pitch and yaw planes are computed.

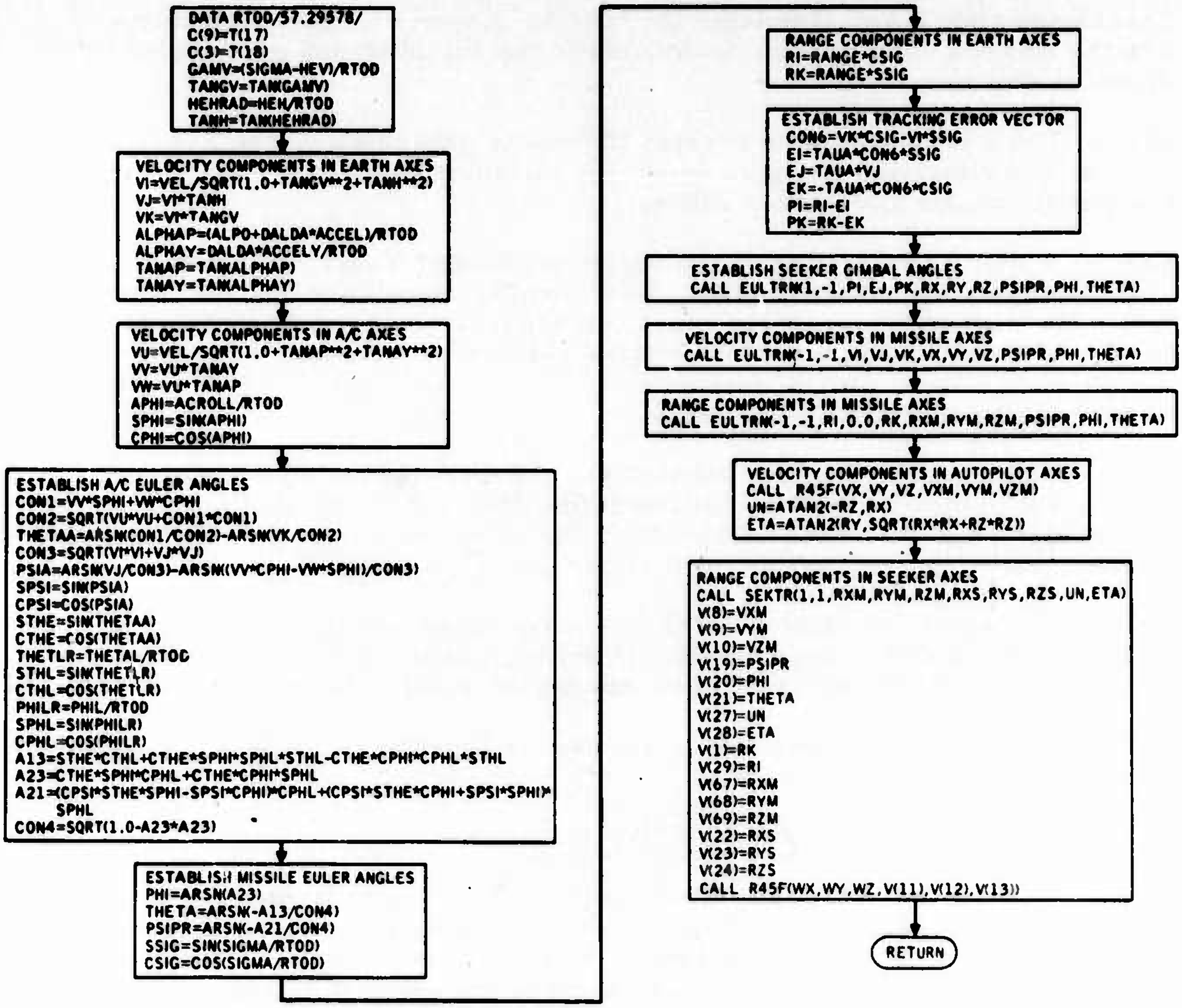


Figure 11. Subroutine Setic Flow Chart

(U) The Seeker subroutine has been modified for the CAS system simulation to accommodate two other subroutines which simulate tracker and gyro dynamics. The respective subroutines are Track and Gyro; their addition facilitates the replacement of different trackers and gyro models into the simulation.

(U) The Track subroutine accepts error signals from the Universal Seeker subroutine and simulates the tracker dynamics. Its output signals are the missile acceleration commands to the autopilot and precession rate signal to the gyro torquer.

(U) The Gyro subroutine accepts the inputs generated by the Track subroutine and simulates the gyro dynamics including drift. Its outputs are the gimbal angles and gimbal rates.

(U) A FORTRAN listing of the Universal Seeker Track and Gyro subroutines are shown in Tables VII, VIII, and IX, respectively. The subroutine block diagram and flow charts appear in Figures 12, 13, 14 and 15, respectively. Tables X, XI, and XII contain a glossary of terms.

2. 3. 5 Aimpoint Wander Subroutine

(U) The Aimpoint Wander subroutine, GWAND, is called out within the Seeker subroutine and either simulates the apparent target motion caused by the wandering of the seeke: airpoint or the actual motion of an evasive target. In both cases, the subroutine input is the boresight range R_{XS}.

(U) The equations implemented in each of these options are shown in Tables XIII and XIV, respectively. If neither option is desired, setting the parameter C(103) to zero will cause the entire subroutine to be bypassed.

(U) A FORTRAN listing of this subroutine appears in Table XV and its flow chart is shown in Figure 16.

2. 3. 6 Angle Restoration Bias (ARB) Subroutine

(U) The Angle Restoration Bias subroutine serves to implement the guidance law incorporated in the CAS missile. It operates on the acceleration commands from the Seeker subroutine to provide steering commands for the Autopilot subroutine. A FORTRAN listing of the subroutine appears in Table XVI. A block diagram and flow chart of the subroutine appear in Figures 17 and 18, respectively.

2. 3. 7 Blind Range Filter (BRF) Subroutine

(U) This subroutine simply provides the filtering for commands to the autopilot subroutine when blind range is reached. The FORTRAN listing for this subroutine appears in Table XVII. The subroutine block diagram and flow chart appear in Figures 19 and 20.

TABLE VII. UNIVERSAL SEEKER FORTRAN LISTING

```
$       FORTRAN LSTOU,DECK
CUSEK         UNIVERSAL SEEKER
        SUBROUTINE MSEEK                                                      SEEK0020
        COMMON /SSAM1/ READ,DELT,AUTOT,TIME
        COMMON /SSAM2/ V  (250),T  (250),C  (250)
        COMMON /TRAKER/ COUNT,TR,N1,OFFX,OFFY
        COMMON /TRAKZ / TEAPO,TEAYO,DTEAP,DTEAY,WYSC,WZSC
        COMMON/GYR/VSY,VSP,WXS,WYS,WZS
        EQUIVALENCE                                                           SEEK0070
       1 (V(22),RXS    ),(V(23),RYS    ),(V(24),RZS    ),(V(25),TEAP  ),     SEEK0080
       2 (V(26),TEAY   ),(V(17),AZCMD  ),(V(18),AYCMD  ),(V(27),UN    ),     SEEK0090
       3 (V(28),ETA    ),       (V(31),EP1),        (V(32),EP2)
        EQUIVALENCE                                                           SEEK0110
       1 (V(53),WX     ),(V(54),WY     ),(V(55),WZ     ),(V(56),DWX   ),     SEEK0120
       2 (V(57),DWY    ),(V(58),DWZ    ),(V(59),AX     ),(V(60),AY    ),     SEEK0130
       3 (V(61),AZ     ),(V(62),VX     ),(V(63),VY     ),(V(64),VZ    )      SEEK0140
        EQUIVALENCE
       0(V(104),VS2),       (V(105),VS1),        (V(110),WND)
        EQUIVALENCE                                                           SEEK0150
       1(V(66),TOTMIS),(V(70),EMJ   ),(V(71),EMK    )                         SEEK0160
       2,(V(50),TSMISS),(V(51),YMISS ),(V(52),ZMISS )                         SEEK0170
        EQUIVALENCE
       1(C(13),TARNGE),(C(14),GK   ),(C(15),TAUAP),(C(16),OMEGAL),
       2(C(17),C1 ),(C(18),C2 ),(C(19),C3 ),(C(20),C4 ),(C(21),C5 ),          SEEK0200
       3(C(22),C6 ),(C(23),C7 ),(C(24),C8 ),(C(25),C9 ),(C(26),C10),          SEEK0220
       4(C(27),C11),(C(28),C12),(C(29),C13),(C(30),C14),(C(31),C15),          SEEK0210
       5(C(32),C16),(C(33),C17),(C(34),C18),(C(35),C19),(C(36),C20),          SEEK0230
       6(C(37),C21),(C(38),C22),(C(39),C23),(C(40),AK1),(C(41),TG     )       SEEK0240
        EQUIVALENCE
       1(C(109),XK1),      (C(110),XK2),      (C(111),PK1),      (C(112),TAU1),
       2(C(113),TAU2),     (C(114),IB),       (C(115),TC)
        DATA   RTOD/57.2957795/
        NAMELIST/NAMS/RXS,ERXS,EMJ,EMK,TOTMIS,TIME,DELT
        IF (READ.EQ.0.0) GO TO 50                                             SEEK0250
C       C(13) THROUGH C(42) ARE RESERVED FOR THIS SUBROUTINE                  SEEK0260
C       C(42) IS DRIFT CONTROL. SET TO +1.0 TO INCLUDE DRIFT                  SEEK0270
        TEAP=-RZS/RXS                                                         SEEK028
        TEAY=RYS/RXS                                                          SEEK0290
        WZSO=0.0                                                              SEEK0310
        WYSO=0.0                                                              SEEK0320
        SINSIG=SIN(T(3)/RTOD)                                                 SEEK0330
        COSSIG=COS(T(3)/RTOD)                                                 SEEK0340
        IF (C(103).EQ.0.0) CALL GWAND(RXS,ERY,ERZ)                            SEEK0360
C                                                                             SEEK0370
C       TRACKING ERROR ANGLES                                                 SEEK0380
     50 CONTINUE                                                              SEEK0390
        IF (C(103).EQ.0.0) GO TO 51                                           SEEK0400
        CALL GWAND (RXS,ERY,ERZ)                                              SEEK0410
        CALL EULTRN(0,-1,0.0,ERY,ERZ,ERXM,ERYM,ERZM,YAW,ROLL,PITCH)           SEEK0420
        CALL SEKTR (0,1,ERXM,ERYM,ERZM,EXS,EYS,EZS,UN,ETA)                    SEEK0430
        ESUM=RXS+EXS                                                          SEEK0440
        YMISS=RYS+EYS                                                         SEEK0450
        ZMISS=RZS+EZS                                                         SEEK0460
        GO TO 52                                                              SEEK0470
     51 ESUM=RXS                                                              SEEK0480
        YMISS=RYS                                                             SEEK0490
        ZMISS=RZS                                                             SEEK0500
     52 TEAP=-ZMISS/ESUM                                                      SEEK051
        TEAY=YMISS/ESUM                                                       SEEK0520
        IF (ABS(TEAP).GE.TARNGE) GO TO 62                                     SEEK0540
```

```
      IF (ABS(TEAY).GE.TARNGE) GO TO 62                                 SEEK0550
      CALL DIF(TEAP,DTEAP,TEAPO)                                        SEEK0560
      CALL DIF(TEAY,DTEAY,TEAYO)                                        SEEK0570
      IF (DTEAP) 80,82,81                                               SEEK 571
   80 CALL SPTEST(TEAP,DTEAP,-TARNGE)                                   SEEK 572
      GO TO 82                                                          SEEK 573
   81 CALL SPTEST(TEAP,DTEAP, TARNGE)                                   SEEK 574
   82 IF (DTEAY) 83,85,84                                               SEEK 575
   83 CALL SPTEST(TEAY,DTEAY,-TARNGE)                                   SEEK 576
      GO TO 85                                                          SEEK 577
   84 CALL SPTEST(TEAY,DTEAY, TARNGE)                                   SEEK 578
   85 CONTINUE                                                          SEEK 579
      GO TO 65                                                          SEEK0580
   62 TEAP=0.0                                                          SEEK0590
      DTEAP=0.0                                                         SEEK0600
      TEAPO=0.0                                                         SEEK0610
      TEAY=0.0                                                          SEEK0620
      DTEAY=0.0                                                         SEEK0630
      TEAYO=0.0                                                         SEEK0640
C                                                                       SEEK0650
C     CONTROL COMMAND                                                   SEEK0660
   65 CONTINUE
      CALL TRACK
      CALL GYRO
      CALL SEKTR(1,1,-VX,-VY,-VZ,VRXS,VRYS,VRZS,UN,ETA)                 SEEK1200
      CALL VECTV(VRXS,VRYS,VRZS,RXS,RYS,RZS,WXS,WYS,WZS,DRXS,DRYS,DRZS) SEEK1220
      CALL SPTEST(RXS,DRXS,C(3))                                        SEEK1222
      CALL SPTEST(RXS,DRXS,C(9))                                        SEEK1224
      CALL SPTEST(RXS,DRXS,10.)                                         SEEK1226
      IF ((V(1).GT.0.0).AND.(ESUM.GT.10.0)) GO TO 140                   SEEK1260
      DTO=  -(ESUM/DRXS)                                                SEEK1240
      TEND=1.0                                                          SEEK1280
      YMISS=YMISS+DTO*DRYS                                              SEEK1290
      ZMISS=ZMISS+DTO*DRZS                                              SEEK1300
      V(50)=SQRT(V(51)**2+V(52)**2)                                     SEEK1310
      V(77)=C(9)/VRXS                                                   SEEK1320
      V(78)=C(3)/VRXS                                                   SEEK1330
      V(79)=ATAN2(V(1),V(29))                                           SEEK1340
      V(80)=ATAN2(V( 30),V(29))                                         SEEK1350
  140 CALL INTER(DRXS,DRX1,DRX2,RXS0,RXS)                               SEEK1360
      CALL INTER(DRYS,DRY1,DRY2,RYS0,RYS)                               SEEK1370
      CALL INTER(DRZS,DRZ1,DRZ2,RZS0,RZS)                               SEEK1380
      RI=V(29)*COSSIG+V(1)*SINSIG                                       SEEK1390
      RJ=V(30)                                                          SEEK1400
      RK=-V(29)*SINSIG+V(1)*COSSIG                                      SEEK1410
      VI=V(36)*COSSIG+V(38)*SINSIG                                      SEEK1420
      VJ=V(37)                                                          SEEK1430
      VK=-V(36)*SINSIG+V(38)*COSSIG                                     SEEK1440
      EMJ=RJ-RI*VJ/VI                                                   SEEK1450
      EMK=RK-RI*VK/VI                                                   SEEK1460
      TOTMIS=SQRT(EMJ**2+EMK**2)                                        SEEK1470
      IF(RXS.LE.15.)      WRITE(6,NAMS)
  120 RETURN                                                            SEEK1480
      END                                                               SEEK1490
```

TABLE VIII. TRACK ROUTINE FORTRAN LISTING

```
C        A2 MAVII TRACKER A-6  WITH LAG ONLY
      SUBROUTINE TRACK
      COMMON /SSAM1/ READ,DELT,AUTOT,TIME
      COMMON /SSAM2/ V  (250),T  (250),C  (250)
      COMMON /SSAM/ IEND,ND,TNEXT,VMIN,STPMX,S12345,SUM222
     1,CETA,SETA,CNU,SNU,TMAX,N4,LNV(50),TITLE(250),DELTO,RTITLE(9)
     2,IFGEN,IMFGEN,MFGEN2,IFG2N
      COMMON /GYR/VSY,VSP,WXS,WYS,WZS
      COMMON /TRAKZ / TEAPO,TEAYO,DTEAP,DTEAY,WYSC,WZSC
      EQUIVALENCE
     1(V(17),AZCMD),   (V(18),AYCMD),    (V(25),TEAP),    (V(26),TEAY),
     2(V(22),RXS),   (V(112),TEAYD), (V(113),TEAPD), (V(116),VSYP),
     3(V(117),VSPP)
      EQUIVALENCE
     1(C(142),SK),    (C(143),AKT),    (C(144),TS),    (C(145),OMEGLD),
     2(C(146),GKK),   (C(147),BIAS),   (C(148),TLDP),  (C(149),TLGP),
     3(C(150),TLDY),  (C(151),TLGY), (C(152),SPOT)
      NAMELIST
     A/NAMB/
     BTEAY,TEAYD,TEAP,TEAPD,TEAYS,TEAPS,SUM1,VSYP,VSPP,AYCMD,AZCMD,VSY,
     CVSP,TIME,GLVSYO,GLVSPO,TLDP,TLGP,TLDY,TLGY,TEAPK,TEAYK,RKAMG,SPXS
      DATA  RTOD/57.2957795/
      SPXS=RXS/SPOT
      CALL FGEN1(RDUMG,SPXS,RKAMG,-1)
      IF(READ.NE.0.0)  GO TO 10
      GO TO 14
   10 SUM1=BIAS
      GO TO 16
   14 IF(TIME.LT.SUM1) GO TO 20
   16 TEAPK=TEAP*RKAMG
      TEAYK=TEAY*RKAMG
      TEAYD=RTOD*TEAYK
      TEAPD=RTOD*TEAPK
      CALL FGEN1(TDUMY,TEAYD,TEAYS,-1)
      CALL FGEN1(TDUMP,TEAPD,TEAPS,-1)
      CONT=1.
      SUM1=SUM1+TS
   20 CALL TTEST(SUM1)
      VSYP=AKT*TEAYS
      VSPP=AKT*TEAPS
      CALL DIF(VSYP,DVSYP,VDUMY)
      CALL DIF(VSPP,DVSPP,VDUMP)
      CALL LAG(VSPP,DVSPP,GLVSPO,GLVSP,DLGVSP,TLGP,GDUMP)
      CALL LAG(VSYP,DVSYP,GLVSYO,GLVSY,DLGVSY,TLGY,GDUMY)
      AYCMD=GKK*GLVSY
      AZCMD=-GKK*GLVSP
      CALL LIMIT(GLVSY,DLGVSY,OMEGLD,-OMEGLD)
      CALL LIMIT(GLVSP,DLGVSP,OMEGLD,-OMEGLD)
      VSY=GLVSY*SK
      VSP=GLVSP*SK
      IF(CONT.EQ.1.)  WRITE(6,NAMB)
      CONT=0.
      RETURN
      END
```

TABLE IX. GYRO SUBROUTINE FORTRAN LISTING

```
CGYRO       GYRO  SIDE RAIL       GNUT OPTION
      SUBROUTINE GYRO
      DIMENSION  F01B(4),F12E(4),F04C(3)
      COMMON /SSAM1/ READ,DELT,AUTOT,TIME
      COMMON /SSAM2/ V  (250),T  (250),C  (250)
      COMMON /TRAKER/ COUNT,TH,N1
     1     ,OFFX,OFFY
      COMMON
     1/GYR/VSY,VSP,CE,WYS,WZS
      EQUIVALENCE
     1(V(27),UN),       (V(28),ETA)
      EQUIVALENCE
     1(V(53),WA),       (V(54),WY),       (V(55),WZ),       (V(56),DWA),
     2(V(57),DWY),      (V(58),DWZ),      (V(59),OA),       (V(60),AY),
     3(V(61),AZ)
      EQUIVALENCE
     1(V(85),DE),       (V(86),DEXS),     (V(87),E),        (V(88),EXS),
     2(V(89),G1),       (V(90),Q1),       (V(91),DQ1),      (V(92),Q2),
     3(V(93),DQ2),      (V(94),Q1N),      (V(95),Q2N),      (V(96),FFE),
     4(V(97),DFE),      (V(98),FEXS),     (V(99),DFEXS)
      EQUIVALENCE
     1(C(116),W3S),      (C(117),K2T),     (C(118),DUMP),    (C(119),RAIL)
     2,(C(136),GNUT),    (C(137),DFR),     (C(138),DST),     (C(139),DSU),
     3(C(140),DAN),      (C(141),DDU), (C(153),CF1),  (C(154),CF2),
     4(C(155),CF3)
      REAL  I1R,I1RXE,I2E,I2S,    I2EXS,I3S,I3T,I4C,I4D,I4DXC,I1E
      REAL MC,MP,LR,K01B,K02,K12F,K04C,MPX,K3E,K3S,K2E,K2S,K2EXS,K1E,
     1K1BXE,M3,M23,M123,K2T
      REAL KRR,KRT,KGT,KGR,M23S,M123S
      NAMELIST
     A/NAMZZ/
     BWEF,E,FHS,FFXS,ET,EXS,EXSS,EXST,GA2,GBP,GEP,MUXCD,KGR,KGT,
     CK12T,KRR,KRT,M123S,M23S,SE,W13,XEWM,XGEXS,XGSE,XKG,XKR,
     DXKRM,XTE,XU
     E/NAMA/
     1A1,A2,AGB,AGE,B,B1,B2,C1,CA,CB,CD,CE,CF,CH,COSB,COSC,COSD,COSE,
     2COUNT,CX1,CX2,CX3,     D1N,D2N,DB,DBX,DC,DDB,DDE1,DDXC,DE,DE1,
     3DEEXS,DEX,DEXS,DFE,DFEXS,DG1,DG2,DX,DWA,DWBXE,DWDXC,E,F1,EXS,
     4FB,FC,FDB,FDC,FDE,FE,FFE,FEXS,G1,G1N,G1Z,G2,G2N,G2Z,GH,GB2,GBL,
     5GBXE,GC,GE,GEL,GFXS,GS,HDDXC,MC,MP,RE1,RE2,RX1,RX2,SBSF,SEC2,SECB,
     6SECC,SECD,SECE,SINB,SINC,SIND,SINE,STAN,     TAN2,TANC,TANE,
     7TANY,TE,TEA,TEDU,TEI,TEP,TES,TEU,TEXS,TEXSA,TEXSF,TEXSP,TEXSS,
     8TEXSU,TXDU,W1,W12,W2,WA,WBXE,WD,WDXC,WE,WEBXE,WN,WT,     XFM,
     9XMK,XMP,XIM,XIMC,   ES,XS
     A,TAND,TIME,DELT,CX4C
C
C     MAVERICK GYRO ESTIMATED AND CALCULATED PARAMETERS  (7-15-69)
C
      DATA
     1I3S,I3T,I2E,I2S,I2EXS/4.27E 4,2.04E 4,2.36E 4,2.98E 4,2.70E 4/,
     2I1R,I1F,I1RXE/1.46E 4,1.53E 4,2.94E 4/,
     3I4C,I4D,I4DXC/1.75E 3,1.94E 3,2.08E 3/,
     4M3,M23,M123/1.12E 3,2.53E 3,2.95E 3/,
```

TABLE IX. GYRO SUBROUTINE FORTRAN LISTING (CONTINUED)

```
     5K3F,K3S,K1F,K1RXF/0.42E-7,2.10E-7,0.52E-7,1.00E-7/,
     6K2F,K2S,K2FXS/0.30E-7,0.70E-7,0.75E-7/,
     7RCA,RPL,GCA,GPL/10.,4540.,20.,4540./,
     8F01H/33.8,7.3,1.9,0.22/,
     9F12E/22.5,2.1,0.5,0.16/,
     AF04C/11.8,1.3,0.4/,
     BY,K02,K01B,K12E,K04C/1.2,150.,0.,0.,0./,
     CV01B,V12E,V04C/4.0,1.5,2.5/,
     DUS,UBXE,UE,UEXS,UD,UDXC,MPX/1.00,1.00,1.00,1.00,0.50,0.50,2.0/,
     ELR,OL,OT,DUB,THET/0.215,12.0,21.0372,0.50,0./,
     FG,R/980.,57.2957795/
      IF (READ.EQ.0.)  GO TO 3
C
CCCCC INITIAL COMPUTATIONS
C
      M23S=M23**2
      M123S=M123**2
      EXSS=I2FXS-I2S
      MDXCD=I4DXC-I4D
      ET=I2E+I3T
      BEF=I1BXE-I1F
      EEXS=I2E-I2EXS
      SE=I2S-I2E
      EXST=I3T+I2EXS
      EBS=I1B+I2S
      WI3=W3S*I3S
      GHP=GPL/M123
      GEF=GPL/M23
      KRR=9.E-7*RCA/RPL+9.E-10*RCA
      KRT=1.4E-3/(RPL*RCA)+1.9E-7/SQRT(RCA)
      KGT=1.4E-3/(GPL*GCA)+1.9E-7/SQRT(GCA)
      KGR=9.E-7*GCA/GPL+9.E-10*GCA
      XKR=K3E-K3S+KRR-KRT
      XKG=K2F+KGT-KGR/2.
      XKRM=XKR*M3**2
      XGSE=XKRM+M23S*(XKG-K2S)
      XGEXS=M23S*(XKG-K2EXS)
      XTE=XKRM+M23S*(K2EXS-K2S)
      XERM=M123S*(K1E-K1BXE)
      GA2=GA**2
      XU=DUB*W3S**2/980.
      XU=GNUT*XU
      WRITE (6,NAMZ)
      IF(RAIL.EQ.1.0) GO TO 25
      B=UN
      E1=ETA
      GO TO 26
 25   CONTINUE
      B=FTA
      E1=UN
 26   CONTINUE
      EXS=B
      E=E1
      ES=E
      XS=EXS
      KOUNT=0
      KDUMP=DUMP+.01
C
CCCCC MISSILE FRAME RATES AND ACCELERATIONS
C
```

```
    3 CONTINUE
      KOUNT=KOUNT+1
      GB2=GB**2
      AGB=ABS(GB)
      IF (AGB.LE.GBP)  GO TO 210
      GBL=AGB-GBP
      GO TO 220
  210 GBL=0.
  220 CONTINUE
      FB=F01B(1)+F01B(2)*GBL+F01B(3)*SQRT(GA2+GC**2)+F01B(4)*GBL**2
      FB=FB*CF1
      FC=F04C(1)*CF2+(F04C(2)*ABS(GC)+F04C(3)*SQRT(GA2+GB2))*CF3
C
C     MISSILE RAIL POSITION
      IF(RAIL.EQ.1.0) GO TO 40
C            BOTTOM RAIL
      WB=WY
      WC=WZ
      DWB=DWY
      DWC=DWZ
      GB=AY
      GC=AZ
      B=UN
      E1=ETA
      VE=VSY
      VEXS=VSP
      GO TO 42
   40 CONTINUE
C            SIDE RAIL
      WB=WZ
      WC=WY
      DWB=DWZ
      DWC=DWY
      GB=AZ
      GC=AY
      B=ETA
      E1=UN
      VE=VSP
      VEXS=VSY
   42 CONTINUE
      DEEXS=DE*DEXS
      SINB=SIN(B)
      COSB=COS(B)
      SINE=SIN(E1)
      COSE=COS(E1)
      SECE=1./COSE
      TANE=TAN(E1)
      TAN2=TANE**2
      SEC2=SECE**2
      STAN=SECE*TANE
      SINC=COSB*SINE
      C1=ARSN(SINC)
      COSC=COS(C1)
      SECC=1./COSC
      TANC=TAN(C1)
      COSD=COSB*COSE/COSC
      SECD=1./COSD
      SIND=SINB/COSC
      TAND=SIND/COSD
      WE=WA*SINB+WC*COSB
```

TABLE IX. GYRO SUBROUTINE FORTRAN LISTING (CONTINUED)

```
      WBXE=WA*COSB-WC*SINB
      WD=-WA*SINC+WB*COSC
      WDXC=WA*COSC+WB*SINC
      DWBXE=DWA*COSB-DWC*SINB-WB*WE
      DWDXC=DWA*COSC+DWB*SINC+WC*WD
      WEBXE=WE*WBXE
      DDXC=WD*WDXC
      HDDXC=HDXCD*DDXC
C
CCCCC TE COMPUTATIONS
C
      MC=-SIND*TANE*(1.+LR*SINC)
      MP=COSD*      (COSB-LR*SINB**2*SINE)/COSB
      XIM=I4C*MP
      CE=SECE*WBXE+TANE*DEXS
      CF=2.*SIND*SECC+SINB*TAN2
      CX2=SINC*SIND**2*DE+CF*DEXS
      CA=FBS*SEC2*TANE
      CX1=TAND*DWDXC-SECD**2*DDXC-TANC*SECC*DEXS**2
      CD=SECE*(I1B*(TANE*DWBXE-SEC2*WEBXE)+BEE*WEBXE)
      CH=I2S*TANE*(SECE*DWBXE-STAN*WEBXE)
      CX3=TANC*SECC*DEXS+CF*DE
      CB=TAND*DWDXC-SECD**2*DDXC-SINC*(SIND*DE)**2
      HE1=XIM*CH+HDXCD*MP*DDXC
      HE2=EXSS*CF*DEXS-WI3*DEXS+XIM*CX1+HDXCD*MP*DDXC
C
CCCCC TEXS COMPUTATIONS
C
      XIMC=I4C*MC
      RX1=CD+CH+SE   *SECE*WBXE*DE+WI3*DE+XIMC*CB+HDXCD*MC*DDXC
      RX2=CD+CH                     +XIMC*CX1+HDXCD*DDXC*MC
C
CCCCC PRECESSION TORQUE
C
      TEXSP=(VE*SECE+VEXS*MC)*K2T
      TEP=-VEXS*K2T*MP
C
CCCCC UNBALANCE TORQUE
C
      GE=GA*SINB+GC*COSB
      GBXE=GA*COSB-GC*SINB
      GS=GA*COSB*COSE+GB*SINE-GC*SINB*COSE
      SBSE=SINB*SINE
      SECB=SINE*COSB
      GEXS=-GA*SECB+GB*COSE+GC*SBSE
      UU=UDXC*(UA*SINC-UB*COSC)+UD*(GA*COSC+GB*SINC)
      XMP=MPX*(1.-COSB+LR*SINB*SBSE)
      TEXSU=(US+UBXE*SECE-UEXS*TANE)*GE-UE*SECE*GBXE+UU*MC
     1-XMP*GE+MPX*(1.+LR*SECB)*SINB*GS
      TEU=-US*GEXS+UEXS*GS+UU*MP-XMP*GEXS
C
CCCCC FRICTION TORQUE
C
      DB=-WB+WA*COSB*TANE-WC*SINB*TANE+DEXS*SECE
      DE1=-WC*COSB-WA*SINB+DE
      DC=COSD*DE1-SIND*SINE*DB
      FDB=SIGN(1.,DB)
      IF(DB.EQ.0.) FDB=0.
      FDC=SIGN(1.,DC)
      IF(DC.EQ.0.) FDC=0.
```

TABLE IX. GYRO SUBROUTINE FORTRAN LISTING (CONTINUED)

```
      FDE=SIGN(1.,DE1)
      IF(DE1.EQ.0.) FDE=0.
      AGE=ABS(GE)
      IF (AGE.LE.GEP) GO TO 230
      GEL=AGE-GEP
      GO TO 240
  230 GEL=0.
  240 CONTINUE
      FE1=F12E(1)*CF2
      FE2=(F12E(2)*GEL+F12E(3)*SQRT(GB2+GBXE**2)+F12E(4)*GEL**2)*CF3
      FE=FE1+FE2
      XFM=FC*FDC+V04C*DC
      TEXSF=-(FB  *FDB+V01B*DB)*SECE-XFM*MC
      TEF=-(FE  *FDE+V12E*DE1)-XFM*MP
C
CCCCC SPRING TORQUE
C
      TANY=TAN(Y*E1)
      XMK=K04C*COSB*TANY
      TEXSS=-(K01B*SECE+K02)*TAN(Y*B)-XMK*MC
      TES=-(K12E+K02*COSB)*TANY-XMK*MP
C
CCCCC ANISOELASTICITY TORQUES
C
      TEXSA=GS*GF*XGSI-GF*GEXS*TANE*XGEXS*GBXE*GE*SECE*XEHM
      TEA=-GEXS*GS*XIE
C
CCCCC DYNAMIC UNBALANCE TORQUE
C
      WT=W3S*TIME+THETZR
      TXDU=XU*SIN(WT)
      TEDU=XU*COS(WT)
C
CCCCC FINAL COMPUTATIONS
C
      TE=G*(TEP+DFR*TEF+DST*TES+DSU*TEU+DAN*TEA+DDU*TEDU)
      TEXS=G*(TEXSP+DFR*TEXSF+DST*TEXSS+DSU*TEXSU+DAN*TEXSA+DDU*TXDU)
      IF(GNUT.EQ.1.0) GO TO 250
C
CCCC  GYRO WITHOUT NUTATION
      CX4C=I4C*DWDXC*SIND/COSD-I4C*DGXC*SECD*SECD*HDXCD*DEXC
      TXGI=(CD*CH)*CX4C*MC
      TEGI=CX4C*MP
      TEXS=TEXS+TXGI
      TE=TE+TEGI
      DE=TEXS/WI3
      DEXS=-TE/WI3
      CALL INTER(DE,DEM1,DEM2,EUO,E)
      CALL INTER(DEXS,DXM1,DXM2,FXO,EXS)
      CALL INTER(DB,DBM1,DBM2,BUO,B)
      CALL INTER(DE1,DE1M1,DE1M2,E1O,E1)
      GO TO 260
  250 CONTINUE
C
CCCC  GYRO WITH NUTATION
      A1=ET+XIM*COSD
      B1=-XIM*SIND*TANE
      A2=XIMC*COSD
      B2=EXST-XIMC*SIND*TANE+I1B*SEC2+I2S*TAN2
      DX=A1*B2-A2*B1
```

TABLE IX. GYRO SUBROUTINE FORTRAN LISTING (CONCLUDED)

```
      W1=(-A2*(EXSS*CE-WI3-XIM*CX3)
     1+W3)*(CA*DE+EEXS*TANE*DE+SE*TANE*DE-XIMC*CX3))/DX
      W2=(A1*(CA*DEXS+SE*CE+WI3-XIMC*CX2+EEXS*DEXS*TANE)+A2*XIM*CX2)/DX
      Q1=(B2*(TE-RE1)-B1*(TEXS-RX1))/DX
      Q2=(A1*(TEXS-RX2)-A2*(TE-RE2))/DX
      CALL DIF(Q1,DQ1,DUMA)
      CALL DIF(Q2,DQ2,DUMB)
      CALL GRATE(1,Q1,DQ1,Q1Z,Q1N,D1N,DUMX1)
      CALL GRATE(1,Q2,DQ2,Q2Z,Q2N,D2N,DUMX2)
      CALL DIF(DB,DDB,DUMR)
      CALL DIF(DE1,DDE1,DUMQ)
      CALL GRATE(1,DB,DDB,BZ,B,DBX,DUM7)
      CALL GRATE(1,DE1,DDE1,E1Z,E1,DEX,DUM8)
      W12=W1*W2
      WN=SQRT(W12)
      FFE=(Q1+W1*Q2Z)/W12+ES
      CALL DIF(FFE,DFE,DUMC)
      FEXS=(Q2-W2*Q1Z)/W12+XS
      CALL DIF(FEXS,DFEXS,DUMD)
      CALL LDSEC(FFE,DFE,EZ,E,DE,0.,1.,WN,0.,DUMX3,DUMX4)
      CALL LDSEC(FEXS,DFEXS,EXSZ,FXS,DEXS,0.,1.,WN,0.,DUMX5,DUMX6)
  260 CONTINUE
      IF(PAIL.EQ.1.0) GO TO 270
      WYS=DEXS
      WZS=DE
      UN=B
      ETA=E1
      GO TO 280
  270 CONTINUE
      WYS=DE
      WZS=DEXS
      UN=E1
      ETA=B
  280 CONTINUE
      KX=MOD(KOUNT,KDUMP)
      IF ((KX.EQ.0 ) .OR.(COUNT.LE.5.))  WRITE(6,NAMA)
      RETURN
      END
```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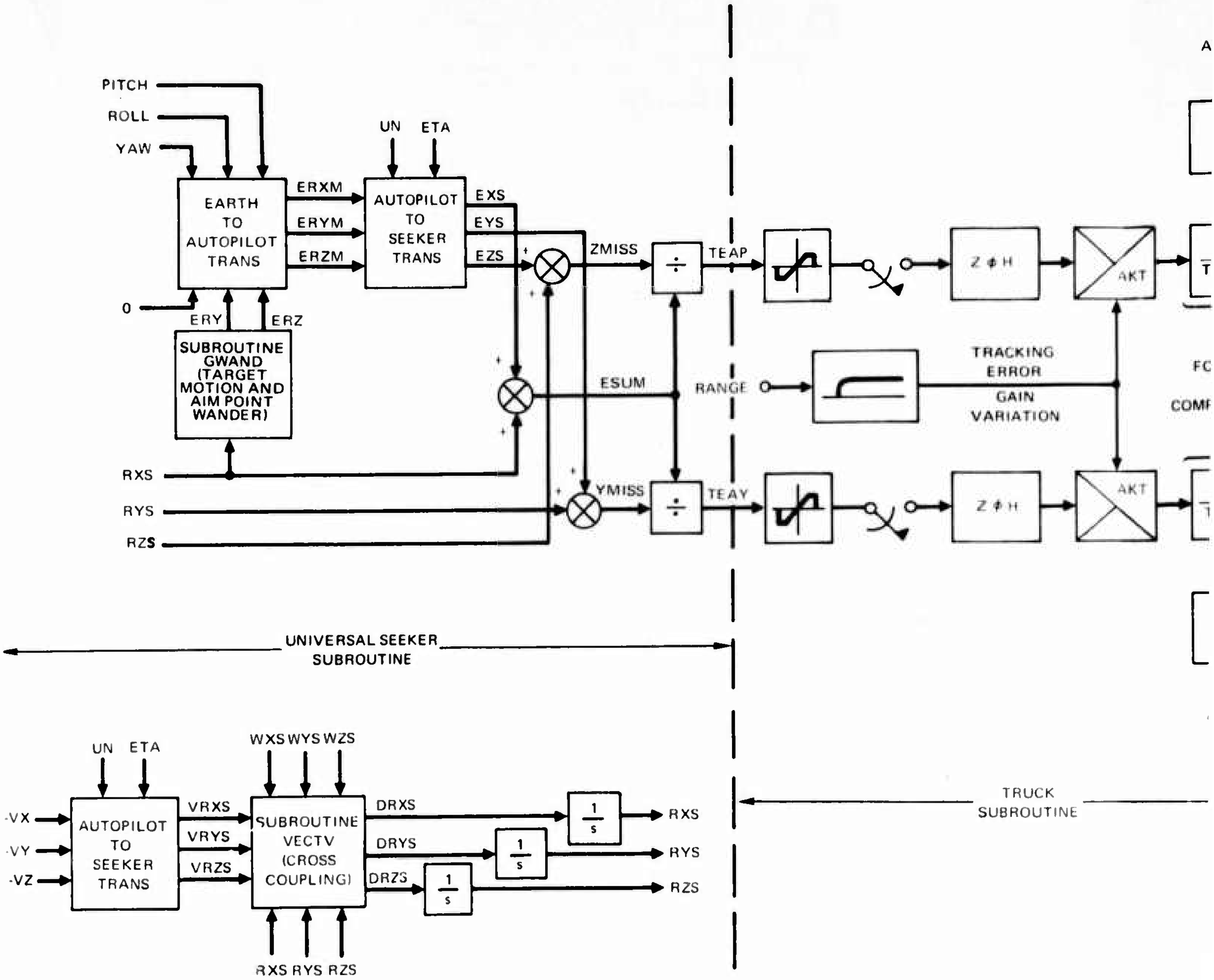

PITCH
ROLL
YAW
EARTH TO AUTOPILOT TRANS
ERXM
ERYM
ERZM
UN
ETA
AUTOPILOT TO SEEKER TRANS
EXS
EYS
EZS
0
ERY
ERZ
SUBROUTINE GWAND (TARGET MOTION AND AIM POINT WANDER)
ZMISS
TEAP
ESUM
RANGE
TRACKING ERROR
GAIN VARIATION
YMISS
TEAY
AKT
RXS
RYS
RZS
UNIVERSAL SEEKER SUBROUTINE
UN
ETA
WXS WYS WZS
-VX
-VY
-VZ
AUTOPILOT TO SEEKER TRANS
VRXS
VRYS
VRZS
SUBROUTINE VECTV (CROSS COUPLING)
DRXS
DRYS
DRZS
RXS
RYS
RZS
RXS RYS RZS
TRUCK SUBROUTINE

2

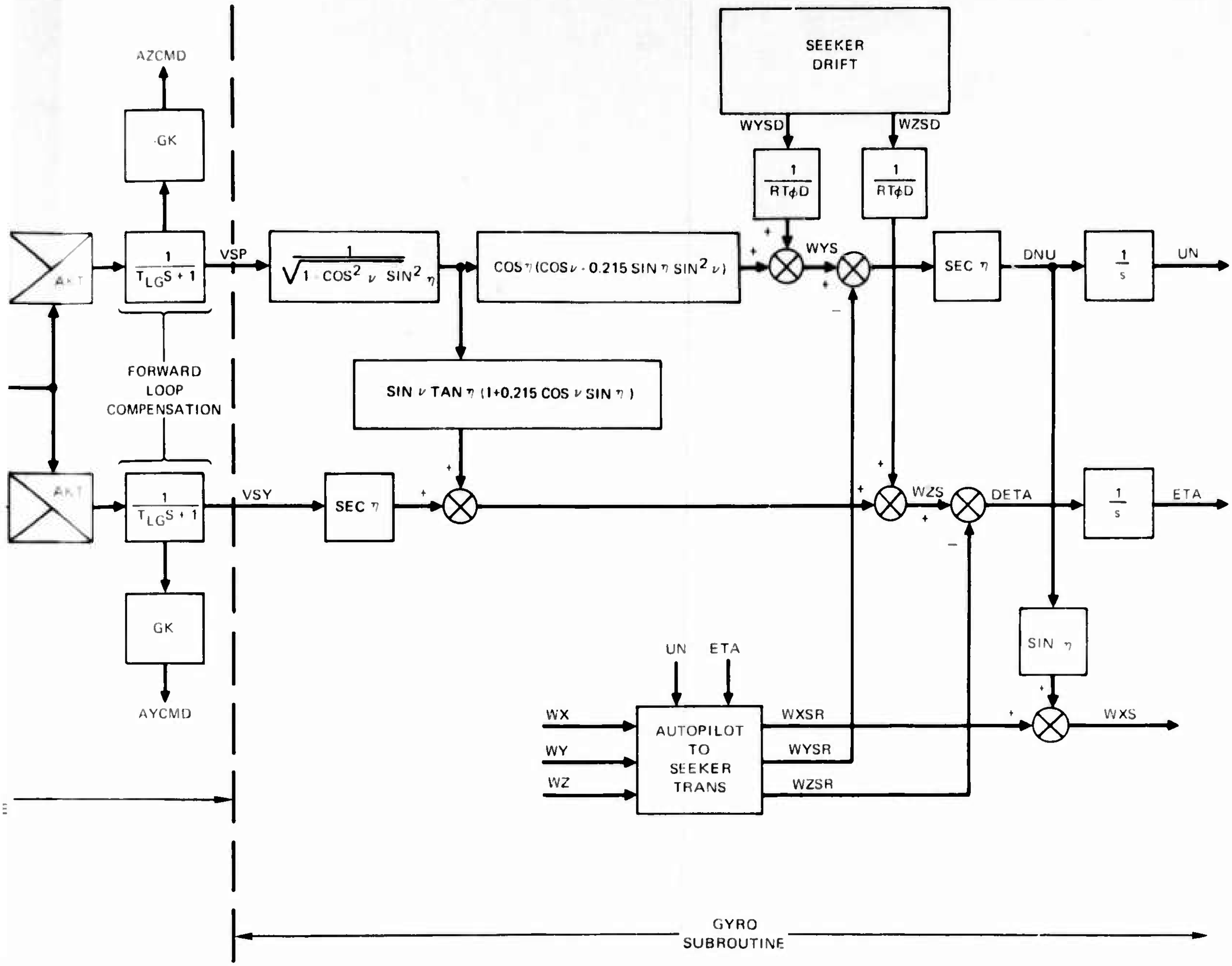

Figure 12. Universal Seeker/ Gyro Subroutine Block Diagram

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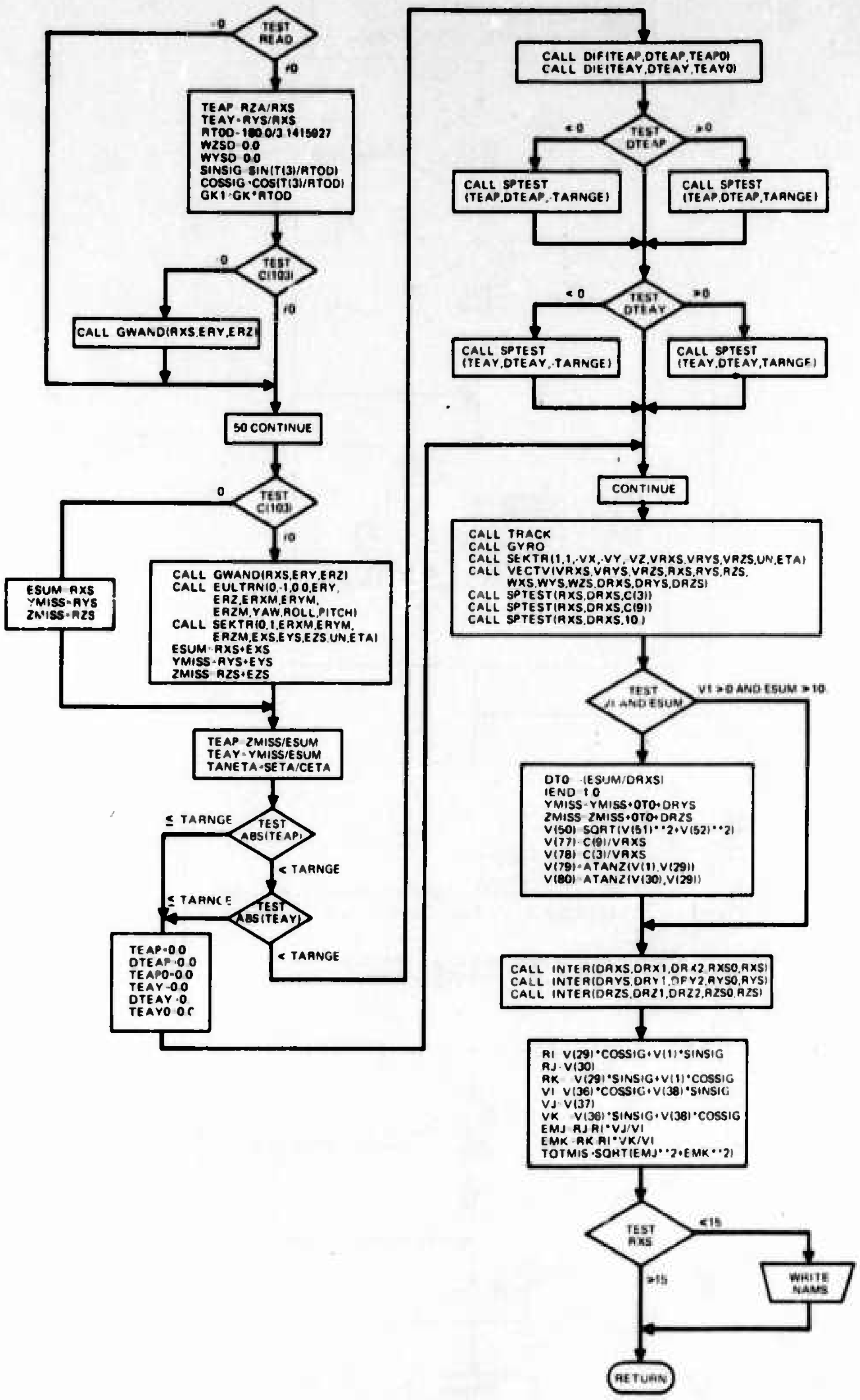


Figure 13. Seeker Subroutine Flow Chart

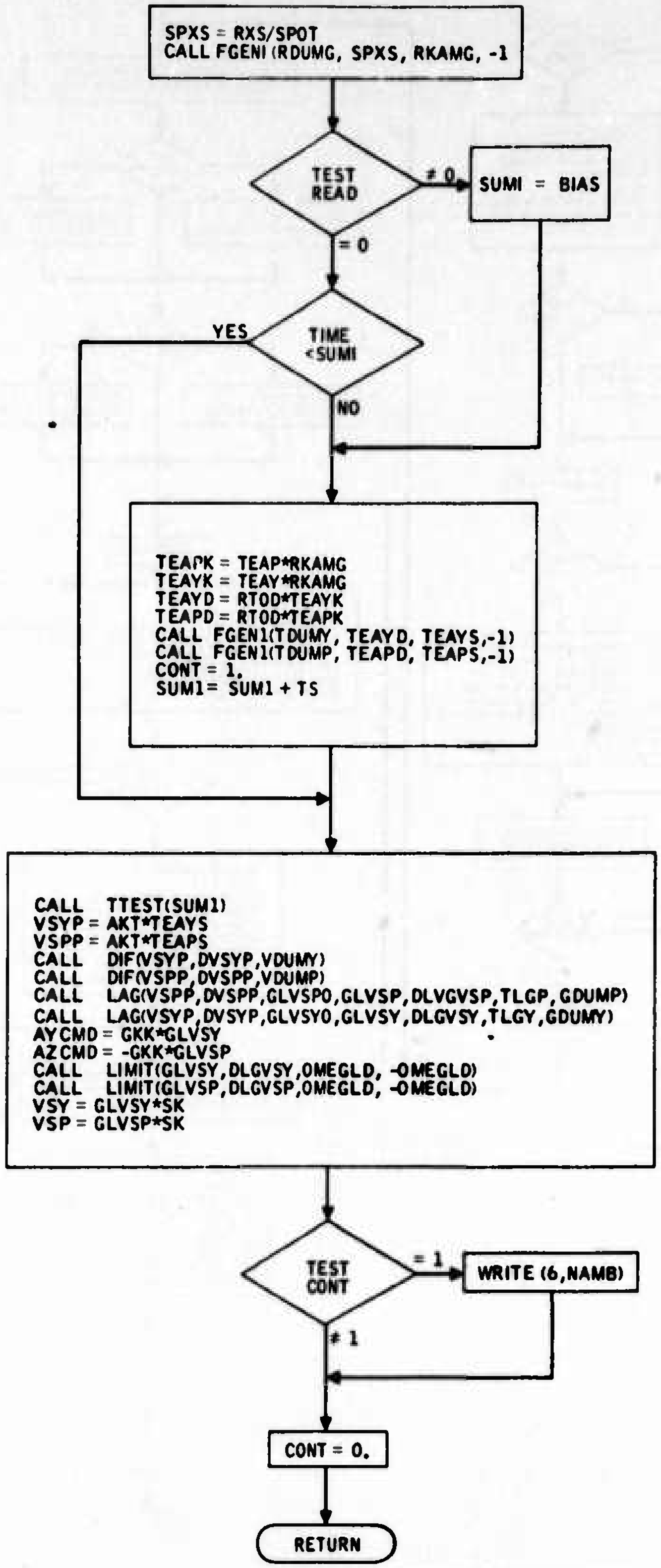
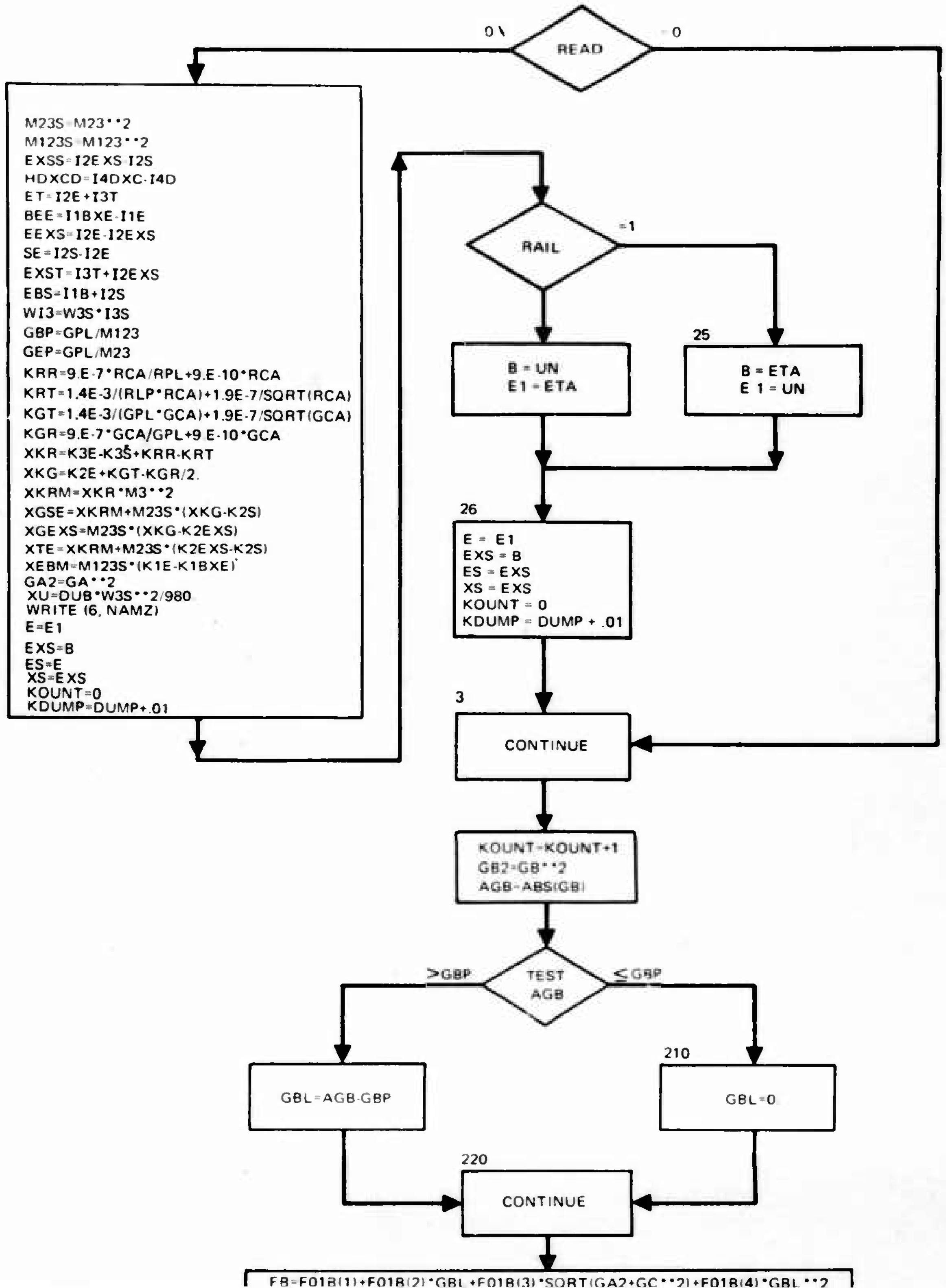


Figure 14. Universal Subroutine TRACK Flow Chart


READ
0\
=0
M23S=M23**2
M123S=M123**2
EXSS=I2EXS·I2S
HDXCD=I4DXC·I4D
ET=I2E+I3T
BEE=I1BXE·I1E
EEXS=I2E·I2EXS
SE=I2S·I2E
EXST=I3T+I2EXS
EBS=I1B+I2S
WI3=W3S*I3S
GBP=GPL/M123
GEP=GPL/M23
KRR=9.E-7*RCA/RPL+9.E-10*RCA
KRT=1.4E-3/(RLP*RCA)+1.9E-7/SQRT(RCA)
KGT=1.4E-3/(GPL*GCA)+1.9E-7/SQRT(GCA)
KGR=9.E-7*GCA/GPL+9.E-10*GCA
XKR=K3E-K3S+KRR-KRT
XKG=K2E+KGT-KGR/2.
XKRM=XKR*M3**2
XGSE=XKRM+M23S*(XKG-K2S)
XGEXS=M23S*(XKG-K2EXS)
XTE=XKRM+M23S*(K2EXS-K2S)
XEBM=M123S*(K1E-K1BXE)
GA2=GA**2
XU=DUB*W3S**2/980
WRITE (6, NAMZ)
E=E1
EXS=B
ES=E
XS=EXS
KOUNT=0
KDUMP=DUMP+.01
RAIL
=1
B = UN
E1 = ETA
25
B = ETA
E 1 = UN
26
E = E1
EXS = B
ES = EXS
XS = EXS
KOUNT = 0
KDUMP = DUMP + .01
3
CONTINUE
KOUNT=KOUNT+1
GB2=GB**2
AGB=ABS(GB)
TEST
AGB
>GBP
≤GBP
GBL=AGB-GBP
210
GBL=0
220
CONTINUE
FB=F01B(1)+F01B(2)*GBL+F01B(3)*SQRT(GA2+GC**2)+F01B(4)*GBL**2

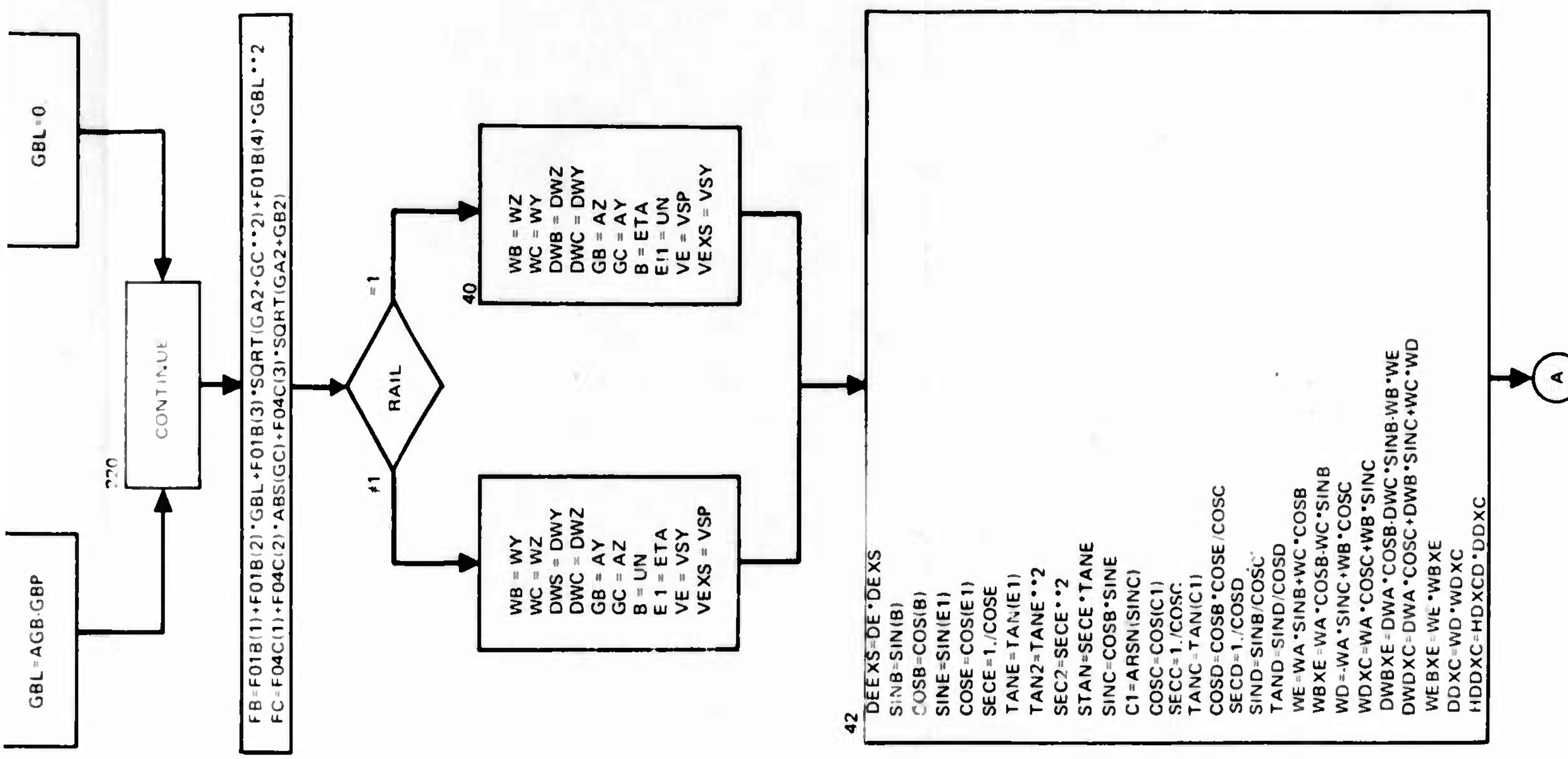


Figure 15. Gyro Subroutine Flow Chart (CAS 6 DOF Simulation)

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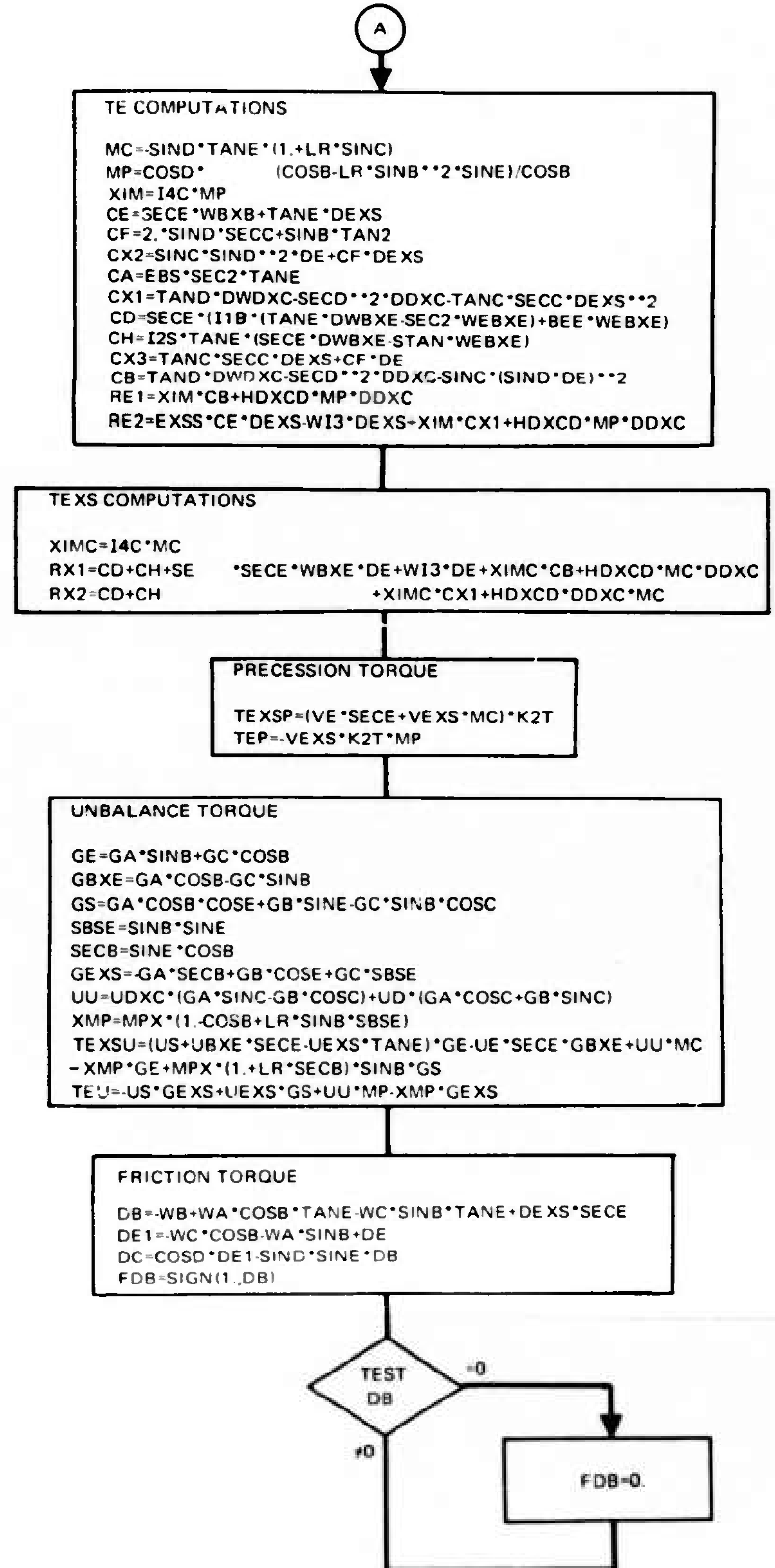
A
TE COMPUTATIONS
MC=-SIND*TANE*(1.+LR*SINC)
MP=COSD* (COSB-LR*SINB**2*SINE)/COSB
XIM=I4C*MP
CE=SECE*WBXB+TANE*DEXS
CF=2.*SIND*SECC+SINB*TAN2
CX2=SINC*SIND**2*DE+CF*DEXS
CA=EBS*SEC2*TANE
CX1=TAND*DWDXC-SECD**2*DDXC-TANC*SECC*DEXS**2
CD=SECE*(I1B*(TANE*DWBXE-SEC2*WEBXE)+BEE*WEBXE)
CH=I2S*TANE*(SECE*DWBXE-STAN*WEBXE)
CX3=TANC*SECC*DEXS+CF*DE
CB=TAND*DWDXC-SECD**2*DDXC-SINC*(SIND*DE)**2
RE1=XIM*CB+HDXCD*MP*DDXC
RE2=EXSS*CE*DEXS-WI3*DEXS+XIM*CX1+HDXCD*MP*DDXC
TEXS COMPUTATIONS
XIMC=I4C*MC
RX1=CD+CH+SE *SECE*WBXE*DE+WI3*DE+XIMC*CB+HDXCD*MC*DDXC
RX2=CD+CH +XIMC*CX1+HDXCD*DDXC*MC
PRECESSION TORQUE
TEXSP=(VE*SECE+VEXS*MC)*K2T
TEP=-VEXS*K2T*MP
UNBALANCE TORQUE
GE=GA*SINB+GC*COSB
GBXE=GA*COSB-GC*SINB
GS=GA*COSB*COSE+GB*SINE-GC*SINB*COSC
SBSE=SINB*SINE
SECB=SINE*COSB
GEXS=-GA*SECB+GB*COSE+GC*SBSE
UU=UDXC*(GA*SINC-GB*COSC)+UD*(GA*COSC+GB*SINC)
XMP=MPX*(1.-COSB+LR*SINB*SBSE)
TEXSU=(US+UBXE*SECE-UEXS*TANE)*GE-UE*SECE*GBXE+UU*MC
-XMP*GE+MPX*(1.+LR*SECB)*SINB*GS
TEU=-US*GEXS+UEXS*GS+UU*MP-XMP*GEXS
FRICTION TORQUE
DB=-WB+WA*COSB*TANE-WC*SINB*TANE+DEXS*SECE
DE1=-WC*COSB-WA*SINB+DE
DC=COSD*DE1-SIND*SINE*DB
FDB=SIGN(1.,DB)
TEST DB
=0
≠0
FDB=0.

2

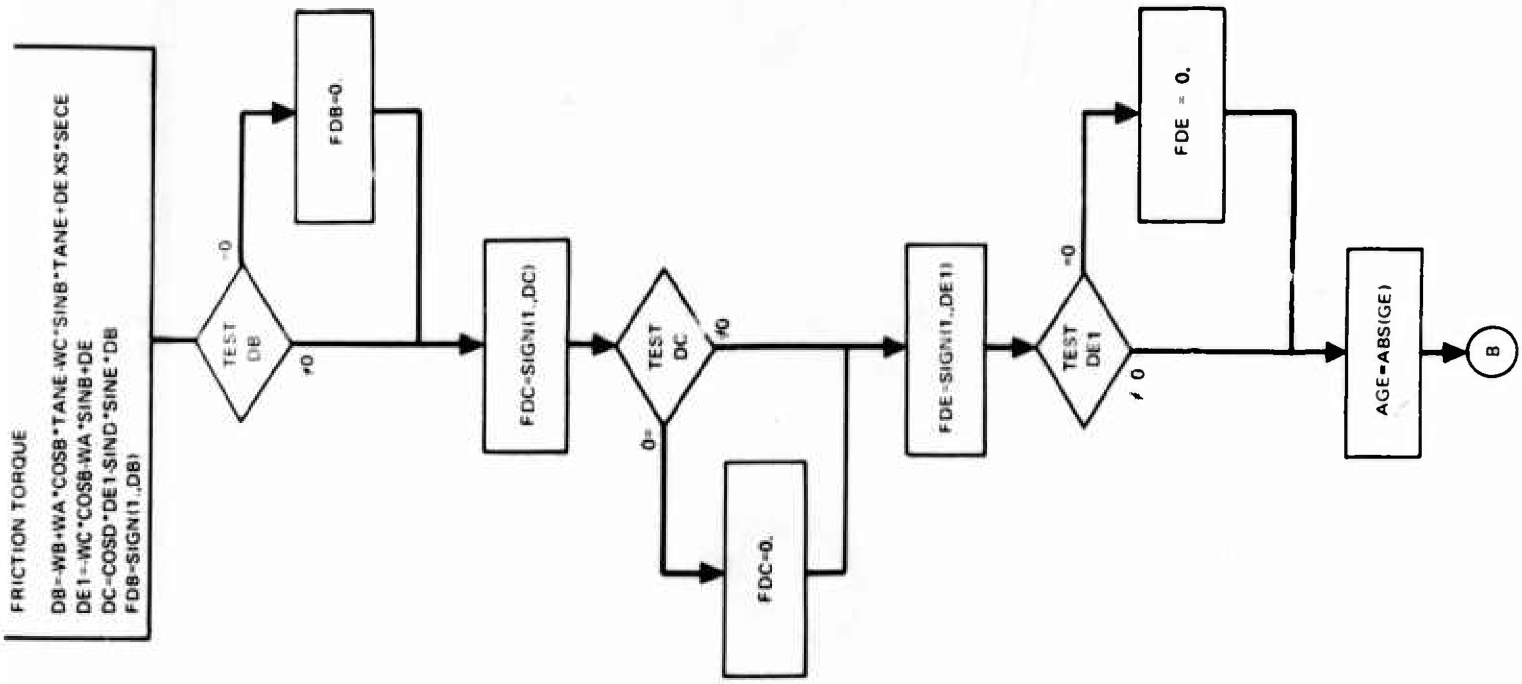

Figure 15. Gyro Subroutine
Flow Chart (CAS 6 DOF
Simulation) (Continued)

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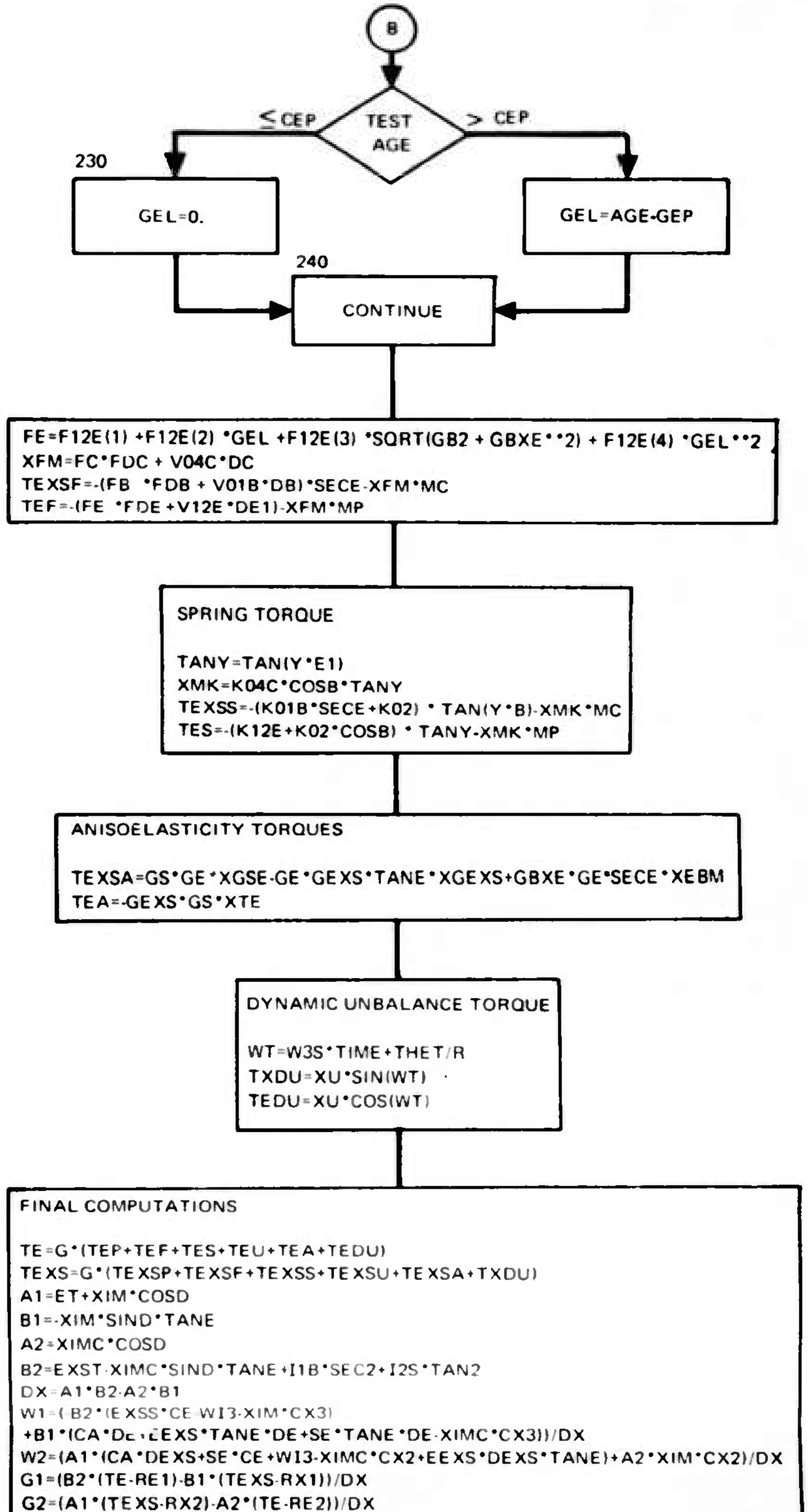
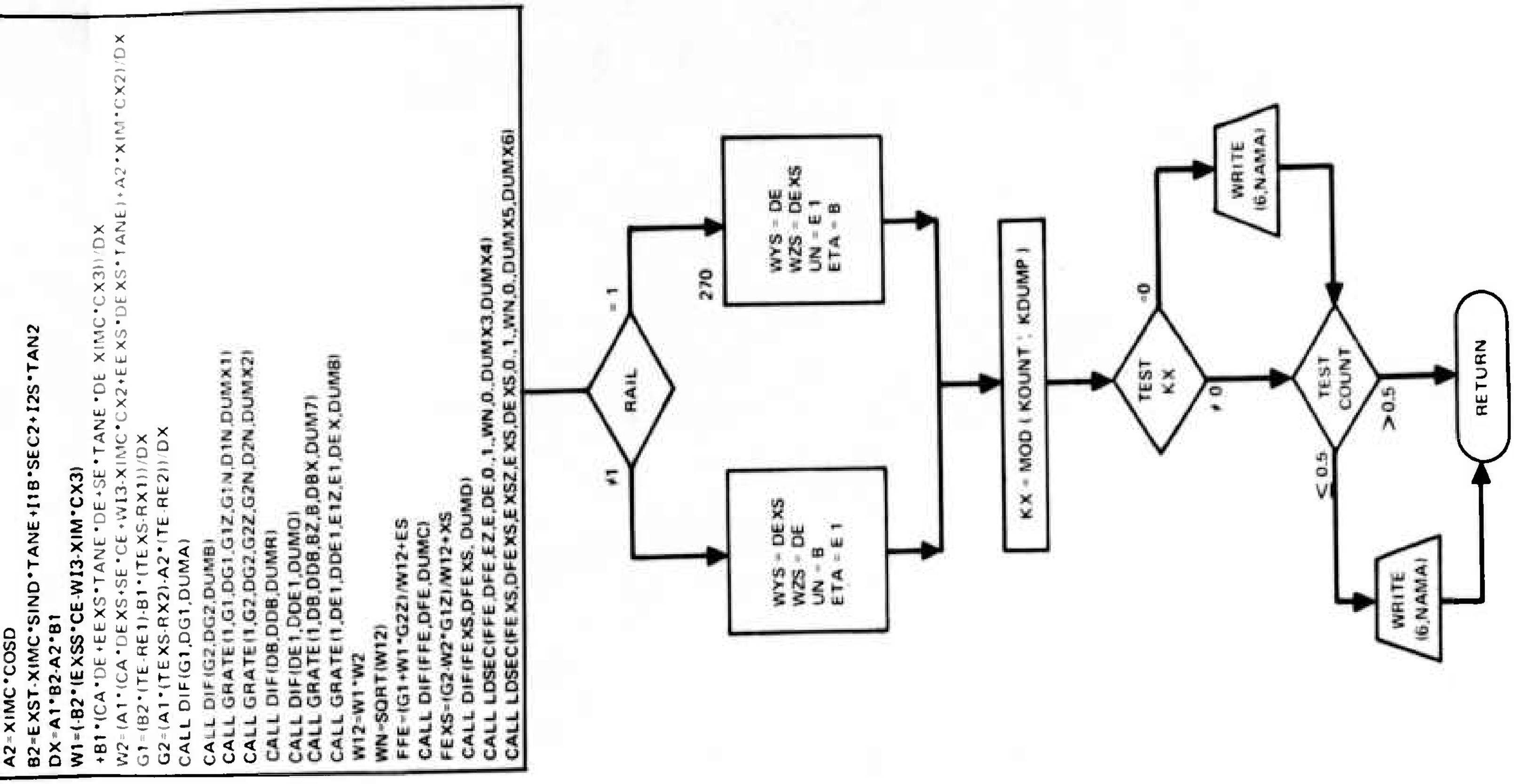

B
TEST AGE
≤ CEP
> CEP
230
GEL=0.
GEL=AGE-GEP
240
CONTINUE
FE=F12E(1) +F12E(2) *GEL +F12E(3) *SQRT(GB2 + GBXE**2) + F12E(4) *GEL**2
XFM=FC*FDC + V04C*DC
TEXSF=-(FB *FDB + V01B*DB)*SECE-XFM*MC
TEF=-(FE *FDE+V12E*DE1)-XFM*MP
SPRING TORQUE
TANY=TAN(Y*E1)
XMK=K04C*COSB*TANY
TEXSS=-(K01B*SECE+K02) * TAN(Y*B)-XMK*MC
TES=-(K12E+K02*COSB) * TANY-XMK*MP
ANISOELASTICITY TORQUES
TEXSA=GS*GE*XGSE-GE*GEXS*TANE*XGEXS+GBXE*GE*SECE*XEBM
TEA=-GEXS*GS*XTE
DYNAMIC UNBALANCE TORQUE
WT=W3S*TIME+THET/R
TXDU=XU*SIN(WT)
TEDU=XU*COS(WT)
FINAL COMPUTATIONS
TE=G*(TEP+TEF+TES+TEU+TEA+TEDU)
TEXS=G*(TEXSP+TEXSF+TEXSS+TEXSU+TEXSA+TXDU)
A1=ET+XIM*COSD
B1=-XIM*SIND*TANE
A2=XIMC*COSD
B2=EXST-XIMC*SIND*TANE+I1B*SEC2+I2S*TAN2
DX=A1*B2-A2*B1
W1=(-B2*(EXSS*CE-WI3-XIM*CX3)
+B1*(CA*DE+EEXS*TANE*DE+SE*TANE*DE-XIMC*CX3))/DX
W2=(A1*(CA*DEXS+SE*CE+WI3-XIMC*CX2+EEXS*DEXS*TANE)+A2*XIM*CX2)/DX
G1=(B2*(TE-RE1)-B1*(TEXS-RX1))/DX
G2=(A1*(TEXS-RX2)-A2*(TE-RE2))/DX



2

Figure 15. Gyro Subroutine Flow Chart (CAS 6 DOF Simulation) (Continued)

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TABLE X. SEEKER (MSEEK) SUBROUTINE

Name	Quality	Units	Coordinate System
V(17) AZCMD	A_{zc}, Elevation maneuver command	g's	Autopilot
V(18) AYCMD	A_{yc}, Azimuth maneuver command	g's	Autopilot
V(22) RXS	R_x, Seeker boresight range	ft	Seeker
V(23) RYX	R_y, Seeker lateral range	ft	Seeker
V(24) RZS	R_z, Seeker normal range	ft	Seeker
V(25) TEAP	ϵ_p, Tracking error angle, pitch	rad	Seeker
V(26) TEAY	ϵ_y, Tracking error angle, yaw	rad	Seeker
V(27) UN	ν, Seeker elevation gimbal angle	rad	
V(28) ETA	η, Seeker azimuth gimbal angle	rad	
V(53) WX V(54) WY V(55) WZ	ω_x' ω_y' ω_z' } Missile body rates in autopilot axes	rad/sec	Autopilot
V(56) DWX V(57) DWY V(58) DWZ	$\dot{\omega}_x'$ $\dot{\omega}_y'$ $\dot{\omega}_z'$ } Scalar components of missile angular acceleration in autopilot axes	rad/sec^2	Autopilot
V(59) AX V(60) AY V(61) AZ	A_x' A_y' A_z' } Propulsive and aerodynamic acceleration components autopilot axes	g's	Autopilot
V(62) VX V(63) VY V(64) VZ	V_x' V_y' V_z' } Missile velocity components in autopilot axes	ft/sec	Autopilot
V(66) TOTMISS	Total Miss Distance	ft	Miss Distance
V(70) EMJ	Y Component of Miss	ft	Miss Distance
V(71) EMK	Z Components of Miss	ft	Miss Distance

TABLE X. SEEKER (MSEEK) SUBROUTINE (CONTINUED)

Name	Quantity	Units
C(13) TARNGE	$\frac{\epsilon_{max}}{2}$, Half the seeker field of view	rad
C(14) GK	K_g, Guidance gain	g's/deg/sec
C(15) TAUAP	τ'_A, Tracker time constant	sec
C(16) OMEGAL	Ω_{CL}, Precession rate limit	rad/sec
C(17) C1	Seeker drift term	rad/sec
C(18) C2	Seeker drift term	rad/sec
C(19) C3	Seeker drift term	rad/sec/g
C(20) C4	Seeker drift term	
C(21) C5	Seeker drift term	1/sec
C(22) C6	Seeker drift term	1/sec
C(23) C7	Seeker drift term	sec
C(24) C8	Seeker drift term	sec
C(25) C9	Seeker frift term	rad/sec/g
C(26) C10	Seeker drift term	rad/sec/g
C(27) C11	Seeker drift term	1/sec/g
C(28) C12	Seeker drift term	rad/sec/g^2
C(29) C13	Seeker drift term	rad/sec/g^2
C(30) C14	Seeker drift term	rad/sec/g^2
C(31) C15	Seeker drift term	rad/sec
C(32) C16	Seeker drift term	rad/sec
C(33) C17	Seeker drift term	rad/sec/g
C(34) C18	Seeker drift term	
C(35) C19	Seeker drift term	1/sec
C(36) C20	Seeker drift term	sec
C(37) C21	Seeker drift term	rad/sec/g
C(38) C22	Seeker drift term	rad/sec/g
C(39) C23	Seeker drift term	rad/sec/g^2
C(40) AK1	K_1, Tracking loop velocity gain	1/sec

TABLE X. SEEKER (MSEEK) SUBROUTINE (CONCLUDED)

Name	Quantity	Units
C(41) TG	Gimbal preload	g
C(42)	Drift control, set to 1.0 to include drift	
C(109)	Not used	
C(110)	Not used	
C(111)	Not used	
C(112)	Not used	
C(113)	Not used	
C(114)	Not used	
C(115)	Not used	

TABLE XI. TRACKER GLOSSARY OF TERMS

Name	Quantity	Units	Coordinate System
	V Array		
V(17)	A_{zc}, Elevation maneuver command	g	Autopilot
V(18)	A_{yc}, Azimuth maneuver command	g	Autopilot
V(22)	R_x, Seeker boresight range	ft	Seeker
V(25)	ϵ_z, Tracking error angle, pitch	rad	Seeker
V(26)	ϵ_y, Tracking error angle, yaw	rad	Seeker
V(112)	TEAYD Tracker error yaw RKAMG	deg	
V(113)	TEAPD Tracker error pitch RKAMG	deg	
V(116)	VSYP - Tracker output signal Pitch	deg/sec	
V(117)	VSPP - Tracker output signal Yaw	deg/sec	
	C Array		
C(142)	SK Torquer gain coefficient	V/deg/sec	
C(143)	AKT - Tracker gain constant	lsec	
C(144)	TS - Sampling period	sec	
C(145)	OMEGLD - Precession rate limit	deg/sec	
C(146)	GKK - Guidance gain	g/deg/sec	
C(147)	BIAS - Sampling rate offset bias	sec	
C(148)	TLDP - Tracker filter lead time constant pitch	sec	
C(149)	TLGP - Tracker filter lag time constant pitch	sec	
C(150)	TLOY - Tracker filter lead time constant-Yaw	sec	
C(151)	TLGY - Tracker filter lag time constant-Yaw	sec	
C(152)	SPOT - Tracker spot size	ft	

TABLE XII. GYRO GLOSSARY OF TERMS

Name	Quantity		Units	Coordinate System
	V Array			
V(27)	ν, Seeker elevation gimbal angle		rad	
V(28)	η, Seeker azimuth gimbal angle		rad	
V(53)	ω'_x	Missile body rates in autopilot axes	rad/sec	Autopilot
V(54)	ω'_y			
V(55)	ω'_z			
V(56)	$\dot{\omega}'_x$	Scalar components of missile angular acceleration in autopilot axes	rad/sec^2	Autopilot
V(57)	$\dot{\omega}'_y$			
V(58)	$\dot{\omega}'_z$			
V(59)	A'_x	Propulsive and aerodynamic acceleration components in autopilot axes	g	Autopilot
V(60)	A'_y			
V(61)	A'_z			
V(85)	DE	Total yaw precession rate		
V(86)	DEXS	Total pitch precession rate		
V(87)	E	Yaw gyro inertial angle		
V(88)	C1	Yaw look angle (indicated)		
V(90)	G1	Forcing function cross-coupled equation 1		
V(91)	DG1	Derivative forcing function cross-coupled equation 1		
V(92)	G2	Forcing function cross-coupled equation 2		
V(93)	DG2	Derivative forcing function cross-coupled equation 2		
V(94)	G1N	Integral forcing function cross-coupled equation 1		
V(95)	G2N	Integral forcing function cross-coupled equation 2		
V(96)	FFE	Forcing function yaw axis		
V(97)	DFE	Derivative forcing function yaw axis		

TABLE XII. GYRO GLOSSARY OF TERMS (CONCLUDED)

Name	Quantity	Units	Coordinate System
	V Array (Continued)		
V(98)	FEXS Forcing function pitch axis		
V(99)	DFEXS Derivative forcing function pitch axis		
	C Array		
C(116)	3S - Gryo motor speed	rad/sec	
C(117)	K2T - Precession torque coefficient	gcm/V	
C(118)	Dump program control logic	B = 0	
C(119)	- Rail control logic	S = 1.0	
C(136)	GNUT - Program logic control - W/O-0, W = 1.0		
C(137)	DFR Coulomb friction drift factor	Dim	
C(138)	DST Spring torque drift factor	Dim	
C(139)	DSU Unbalance drift factor	Dim	
C(140)	DAN Anisoelastic drift factor	Dim	
C(141)	DDU Dynamic unbalance factor	Dim	
C(153)	CF1 Friction factor coefficient	D	
C(154)	CF2 Friction factor coefficient	D	
C(155)	CF2 Friction factor coefficient	D	

TABLE XIII. SUBROUTINE GWAND USED TO SIMULATE AIMPOINT WANDER

(This option is exercised when C(106) ≠ 0)

For

$$C(103) \le RXS \le 8.35 * C(103),$$

$$\left.\begin{aligned} ERY &= \frac{H*RXS}{C(103)*C(105)*C(106)} \\[2ex] ERZ &= \frac{-Z*RXS}{C(103)*C(105)*C(106)} \end{aligned}\right\} \text{Apparent target motion is y and z earth axes}$$

Otherwise

$$ERY = ERZ = 0.$$

Where

$$\left.\begin{aligned} H &= f_1(a) \\ Z &= f_2(a) \end{aligned}\right\} \text{functions } f_1 \text{ and } f_2 \text{ are described by function generators 1A and 1B}$$

and

$$a = C(104)* \left[-0.563 + \sqrt{2.45 - 2.42\left(1 - \frac{C(103)}{RXS}\right)}\right]$$

or

$$a = C(104), \text{ whichever is smaller}$$

TABLE XIV. SUBROUTINE GWAND USED TO SIMULATE TARGET MOTION

(This option is exercised when C(106) = 0)

y_T is target displacement in the positive earth fixed y direction.

$$y_T = V_f \left[t - \tau (1 - e^{-t/\tau})\right]$$

$$\dot{y}_T = V_f (1 - e^{-t/\tau})$$

$$\ddot{y}_T = a\, e^{-t/\tau}$$

Where

a = C(103)* 32.2, initial target acceleration

V_f = C(104), final target velocity

τ = V_f/a

t = time measured from the point when boresight range equals C(105)

TABLE XV. SUBROUTINE GWAND FORTRAN LISTING

```
$        FORTRAN DECK
GWAND            AIM POINT WANDER                                        WAND0010
      SUBROUTINE GWAND(RXS,ERY,ERZ)                                      WAND0020
      COMMON /SSAM1/ READ,DELT,AUTOT,TIME
      COMMON /SSAM2/ V  (250),T  (250),C  (250)
      EQUIVALENCE (C(103),RF),(C(104),A),(C(105),PLOTK), (C(106),PHOTOK)WAND0050
C IF C(103)IS SET TO 0, THIS SUBROUTINE WILL BE BYPASSED                 WAND0060
C IF C(106)IS NON 0,AIM POINT WANDER WILL BE SIMULATED                   WAND0070
C IF C(106)IS SET TO 0, TARGET MOTION WILL BE SIMULATED WHERE            WAND0080
C     1) C(103)=INITAL TARGET ACCEL. IN GS                               WAND0090
C     2) C(104)=FINAL TARGET VELOCITY IN FPS                             WAND0100
C     3) C(105)=SEEKER RANGE AT START OF TARGET MOTION                   WAND0110
C TARGET MOTION OBEYS THE FOLLOWING EQUATIONS                            WAND0120
C     DDY= A*EXP(-T/TAU)                                                 WAND0130
C     DY= T*A*(1-EXP(-T/TAU))                                            WAND0140
C     Y= T*A*(T-TAU*(1-EXP(-T/TAU)))                                     WAND0150
      IF (READ.EQ.0.0)GO TO 50                                           WAND0160
      GX=PLOTK*PHOTOK*RF                                                 WAND0170
      ERY=0.0                                                            WAND0180
      ERZ=0.0                                                            WAND0190
      SMA=0.0                                                            WAND0200
      CALL FGEN1(IA,SMA,H,-1)                                            WAND021
      CALL FGEN1(IB,SMA,Z,-1)                                            WAND022
      IF (C(103).EQ.0.0) GO TO 100                                       WAND0230
      RTST=8.35*RF                                                       WAND0240
      AC=32.2*C(103)                                                     WAND0250
      TAC=C(104)                                                         WAND0260
      TAU=TAC/AC                                                         WAND0270
      GO TO 100                                                          WAND0280
   50 IF (C(103).EQ.0.0) GO TO 100                                       WAND0290
      IF (C(106).EQ.0.0) GO TO 200                                       WAND0300
      IF (RXS.GT.RTST) GO TO 100                                         WAND0310
      IF (RXS.LT.RF)   GO TO 100                                         WAND0320
      RHO=(1.0-RF/RXS)                                                   WAND0330
      SMA=A*(-.563+SQRT(2.45-2.42*RHO))                                  WAND0340
      IF (SMA.GT.A) SMA=A                                                WAND0350
      CALL FGEN1(IA,SMA,H,-1)                                            WAND036
      CALL FGEN1(IB,SMA,Z,-1)                                            WAND037
      ERY=H*RXS/GX                                                       WAND0380
      ERZ=-Z*RXS/GX                                                      WAND0390
  100 RETURN                                                             WAND0400
  200 IF (RXS.LT.C(105)) GO TO 250                                       WAND0410
      TSTART=TIME                                                        WAND0420
      CALL DIF (RXS,DRXS,RXSO)                                           WAND0430
      CALL SPTEST(-RXS,-DRXS,-C(105))                                    WAND0440
      GO TO 100                                                          WAND0450
  250 TTT=TIME-TSTART                                                    WAND0460
      ERY=TAC*(TTT-TAU*(1.0-EXP(-TTT/TAU)))                              WAND0470
      GO TO 100                                                          WAND0480
      END                                                                WAND0490
```

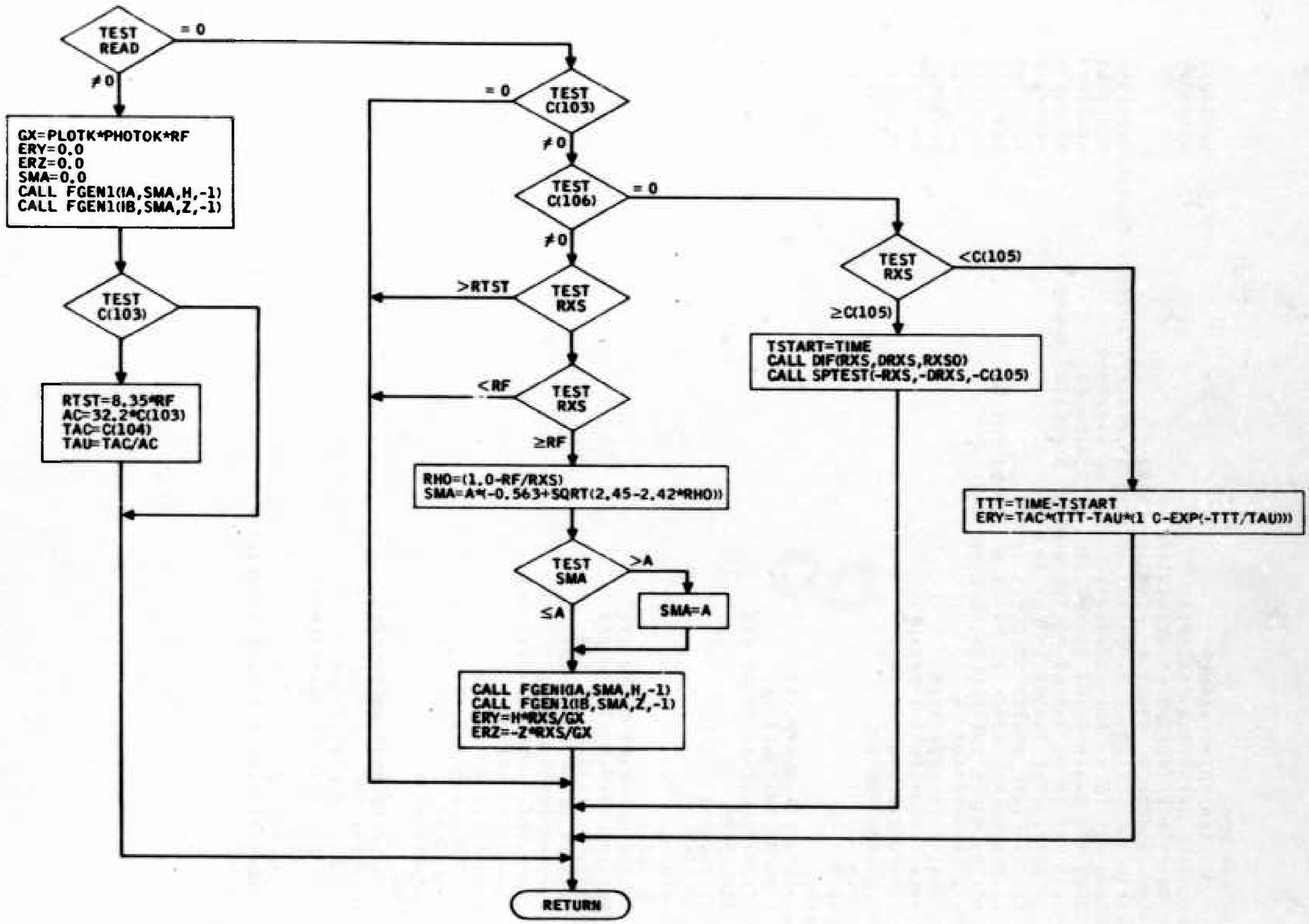


Figure 16. Subroutine GWAND Flow Chart

TABLE XVI. SUBROUTINE ARB FORTRAN LISTING

```
$       FORTRAN DECK
CARB          GUIDANCE LAW MODIFICATION
        SUBROUTINE ARB                                                  ARB 0020
        COMMON /SSAM2/ V  (250),T  (250),C  (250)
        COMMON /SSAM1/ READ,DELT,AUTOT,TIME
        EQUIVALENCE                                                     ARB 0060
       1 (V( 1),ALT   ),(V(2 ),DAC   ),(V( 3),DPC   ),(V( 4),DYC   ),   ARB 0070
       2 (V( 5),DA    ),(V( 6),DP    ),(V( 7),DY    ),(V( 8),VXM   ),   ARB 0080
       3 (V( 9),VYM   ),(V(10),VZM   ),(V(11),WX    ),(V(12),WY    ),   ARB 0090
       4 (V(13),WZ    ),(V(14),AXM   ),(V(15),AYM   ),(V(16),AZM   ),   ARB 0100
       5 (V(17),AZCMD ),(V(18),AYCMD ),(V(19),YAW   ),(V(20),ROLL  ),   ARB 0110
       6 (V(21),PITCH ),(V(22),RXS   ),(V(23),RYS   ),(V(24),RZS   ),   ARB 0120
       7 (V(25),TEAP  ),(V(26),TEAY  ),(V(27),SEGA  ),(V(28),SAGA  ),   ARB 0130
       8 (V(29),RX    ),(V(30),RY    ),(V(31),GEAP  ),(V(32),GEAY  ),   ARB 0140
       9 (V(33),ALPHA ),(V(34),ALPHAP),(V(35),ALPHAY),(V(36),VXE   )    ARB 0150
        EQUIVALENCE                                                     ARB 0160
       1 (V(37),VYE   ),(V(38),VZE   ),(V(39),Q     ),(V(40),VM    ),   ARB 0170
       2 (V(41),AM    ),(V(42),ACP   ),(V(43),ACY   ),(V(44),DWX   ),   ARB 0180
       3 (V(45),DWY   ),(V(46),DWZ   ),(V(47),DDAC  ),(V(48),DDPC  ),   ARB 0190
       5 (V(49),DDYC  ),(V(50),XSMISS),(V(51),YSMISS),(V(52),ZSMISS),   ARB 0200
       6 (V(53),WXP   ),(V(54),WYP   ),(V(55),WZP   ),(V(56),DWXP  ),   ARB 0210
       7 (V(57),DWYP  ),(V(58),DWZP  ),(V(59),AXP   ),(V(60),AYP   ),   ARB 0220
       8 (V(61),AZP   ),(V(62),VXP   ),(V(63),VYP   ),(V(64),VZP   )    ARB 0230
        EQUIVALENCE
       1 (C(109),PSIP0),(C(110),BP),(C(111),AKSIQP)
        IF(READ.EQ.0.) GO TO 10
        PSIPN=0.
     10 ERROR=SEGA*57.295/8*C(7)
        IF (ERROR.GT.0.0) ERROR=0.0                                     ARB 0250
        CALL DIF (ERROR,DE,DE1)                                         ARB 0260
        CALL LAG (DE1,DE,BIASE,BIASEN,DBIAS,C(8),DUMDUM)                ARB 0270
        DPSIP=AZCMD/C(14)
        CALL INTER(DPSIP,DUM1,DUM2,PSIP,PSIPN)
        PSIDFP=PSIP-PSIP0
        IF(PSIDFP.LT.0.) PSIDFP=0.
        ACP=AZCMD-BP+AKSIQP*PSIDFP
        ACY=AYCMD+T(20)
     40 ACP=ACP-BIASE*C(6)+  T(19)
        IF (READ.EQ.0.) GO TO 50
        ACP=0.
        ACY=0.
     50 RETURN
        END
```

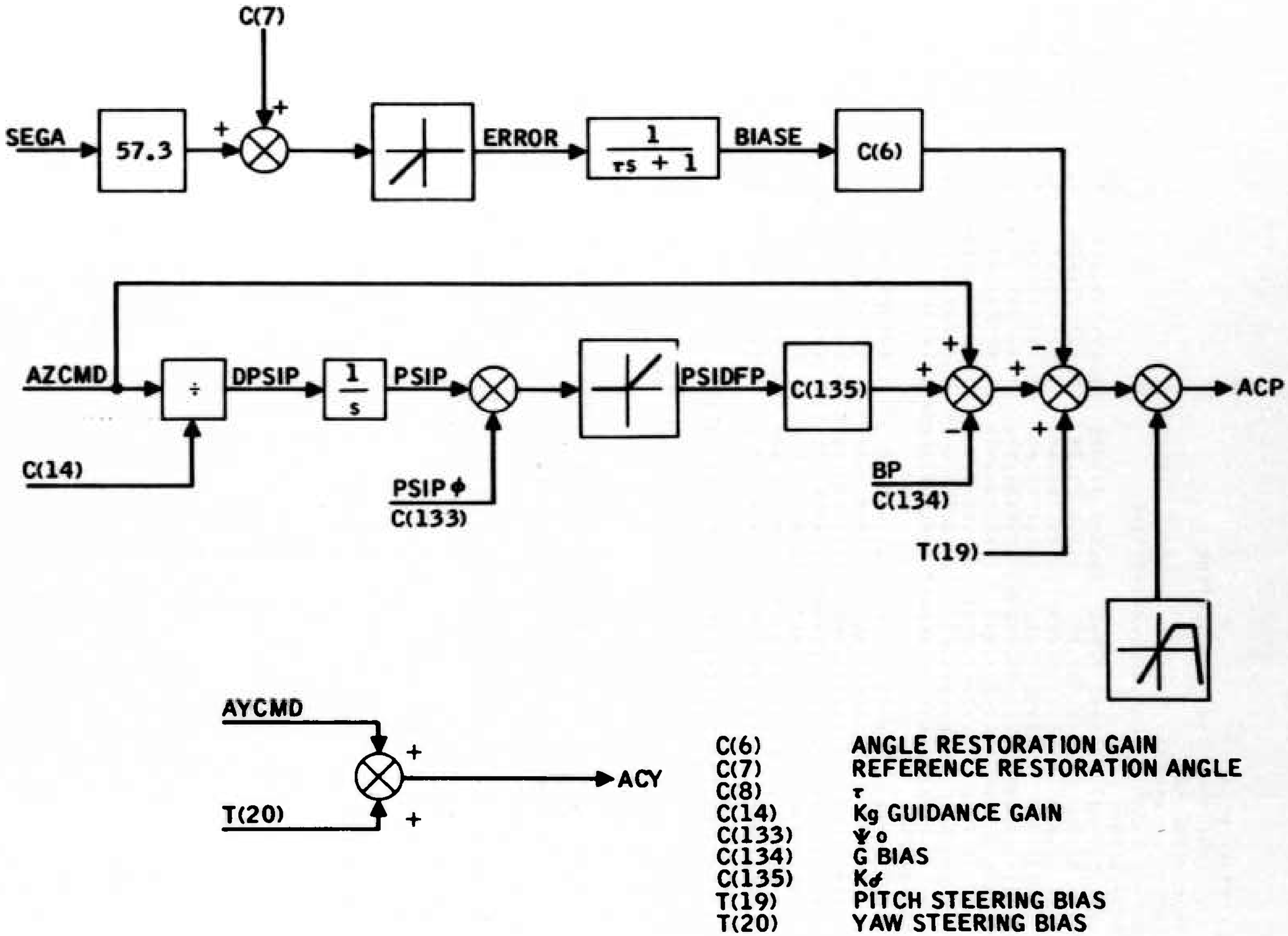


Figure 17. Subroutine ARB Block Diagram

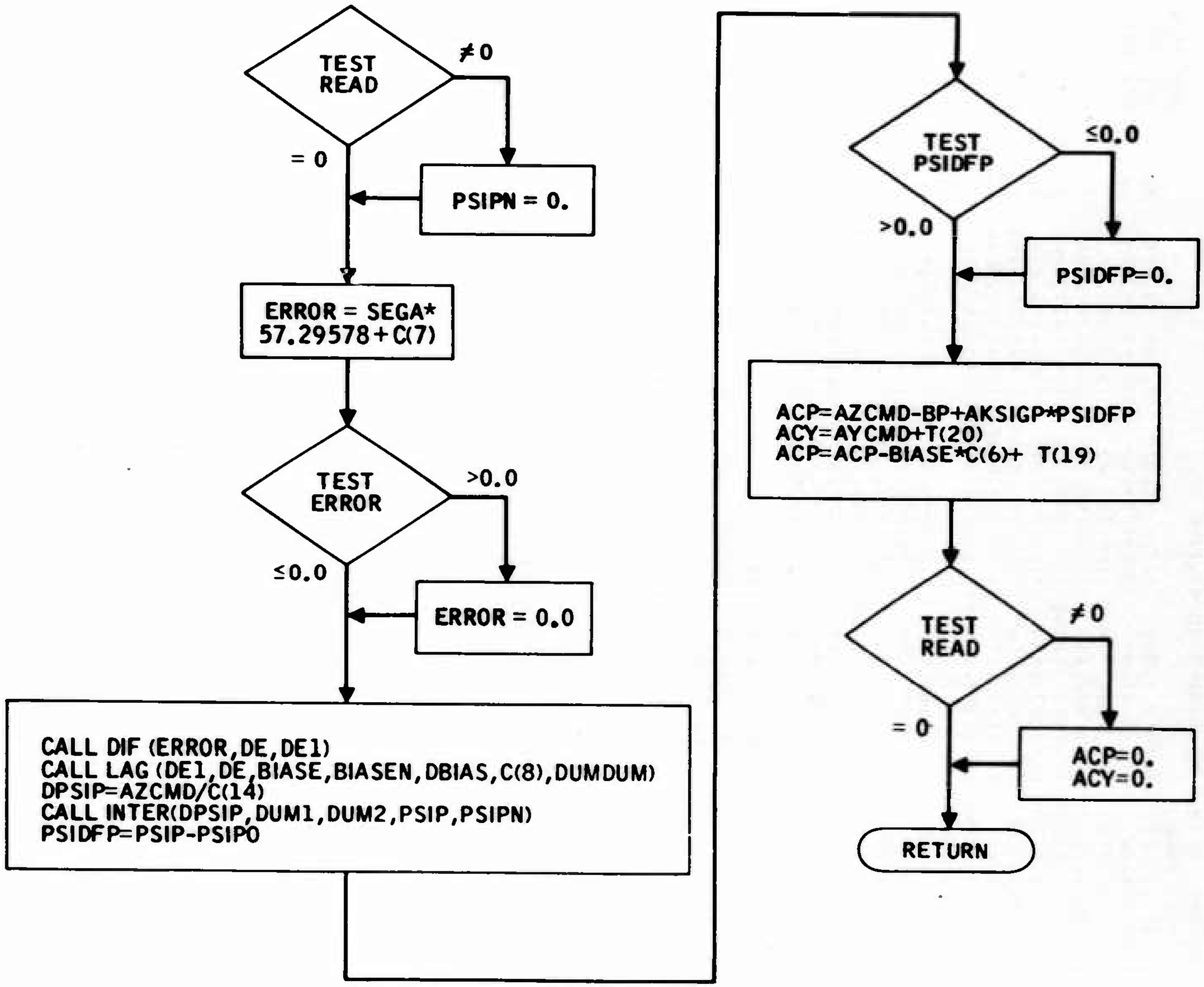


Figure 18. Subroutine ARB Flow Chart

TABLE XVII. SUBROUTINE BRF FORTRAN LISTING

```
$       FORTRAN DECK
CBRF          BLIND RANGE FILTER                                                    BRF 0010
        SUBROUTINE BRF                                                              BRF 0020
        COMMON /SSAM2/ V  (250),T  (250),C  (250)
        COMMON /SSAM1/ READ,DELT,AUTOT,TIME
        EQUIVALENCE                                                                 BRF 0070
      1 (V( 1),ALT   ),(V(2 ),DAC    ),(V( 3),DPC    ),(V( 4),DYC     ),            BRF 0080
      2 (V( 5),DA    ),(V( 6),DP     ),(V( 7),DY     ),(V( 8),VXM     ),            BRF 0090
      3 (V( 9),VYM   ),(V(10),VZM    ),(V(11),WX     ),(V(12),WY      ),            BRF 0100
      4 (V(13),WZ    ),(V(14),AXM    ),(V(15),AYM    ),(V(16),AZM     ),            BRF 0110
      5 (V(17),AZCMD ),(V(18),AYCMD  ),(V(19),YAW    ),(V(20),ROLL    ),            BRF 0120
      6 (V(21),PITCH ),(V(22),RXS    ),(V(23),RYS    ),(V(24),RZS     ),            BRF 0130
      7 (V(25),TEAP  ),(V(26),TEAY   ),(V(27),SEGA   ),(V(28),SAGA    ),            BRF 0140
      8 (V(29),RX    ),(V(30),RY     ),(V(31),GEAP   ),(V(32),GEAY    ),            BRF 0150
      9 (V(33),ALPHA ),(V(34),ALPHAP),(V(35),ALPHAY),(V(36),VXE     )               BRF 0160
        EQUIVALENCE                                                                 BRF 0170
      1 (V(37),VYE   ),(V(38),VZE    ),(V(39),Q      ),(V(40),VM      ),            BRF 0180
      2 (V(41),AM    ),(V(42),ACP    ),(V(43),ACY    ),(V(44),DWX     ),            BRF 0190
      3 (V(45),DWY   ),(V(46),DWZ    ),(V(47),DDAC   ),(V(48),DDPC    ),            BRF 0200
      5 (V(49),DDYC  ),(V(50),TSMISS),(V(51),YSMISS),(V(52),ZSMISS),                BRF 0210
      6 (V(53),WXP   ),(V(54),WYP    ),(V(55),WZP    ),(V(56),DWXP    ),            BRF 0220
      7 (V(57),DWYP  ),(V(58),DWZP   ),(V(59),AXP    ),(V(60),AYP     ),            BRF 0230
      8 (V(61),AZP   ),(V(62),VXP    ),(V(63),VYP    ),(V(64),VZP     )             BRF 0240
        IF (READ.EQ.0.0) GO TO 5                                                    BRF 0250
        COSSIG=COS(T  (3)*3.1415927/180.0)
        SINSIG=SIN(T  (3)*3.1415927/180.0)
      5 IF (RXS.LT.C(9)) GO TO 10                                                   BRF 0280
        CALL DIF(V(43),DSIGY,DUM2)                                                  BRF 0290
        CALL LAG(V(43),DSIGY,XXY0,XXYN,DXXY,C(5),DUM6)                              BRF 0300
        V(75)=V(73)                                                                 BRF 0310
        GO TO 20                                                                    BRF 0320
     10 ACY=XXYN                                                                    BRF 0330
     20 IF (RXS.LT.C(3)) GO TO 40                                                   BRF 0340
        CALL DIF(V(42),DSIGP,DUM1)                                                  BRF 0350
        CALL LAG(V(42),DSIGP,XXP0,XXPN,DXXP,C(5),DUM5)                              BRF 0360
        V(76)=-V(72)*SINSIG+V(74)*COSSIG                                            BRF 0370
        GO TO 50                                                                    BRF 0380
     40 ACP=XXPN                                                                    BRF 0390
     50 RETURN                                                                      BRF 0400
        END                                                                         BRF 0410
```

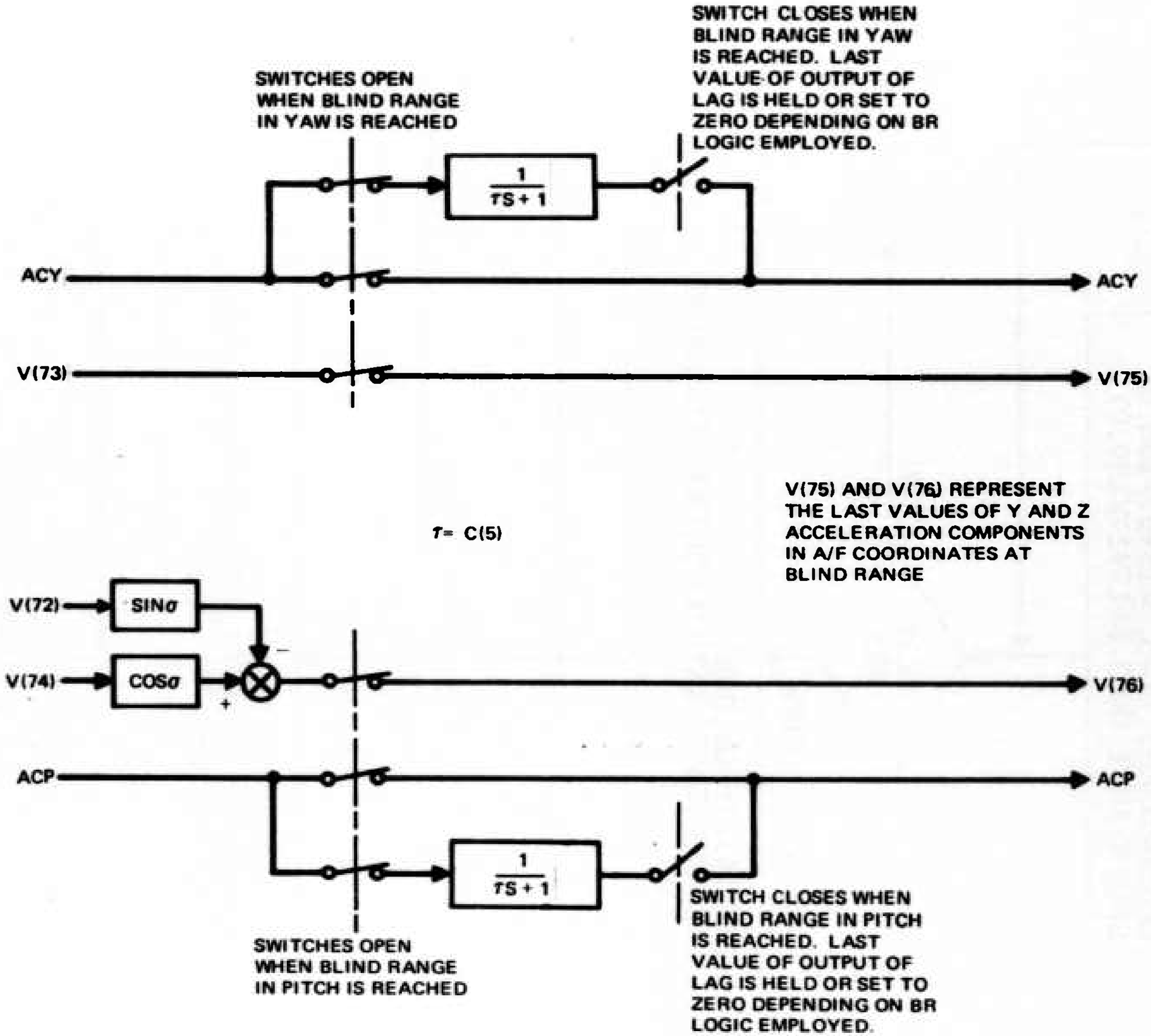


Figure 19. Subroutine BRF Block Diagram

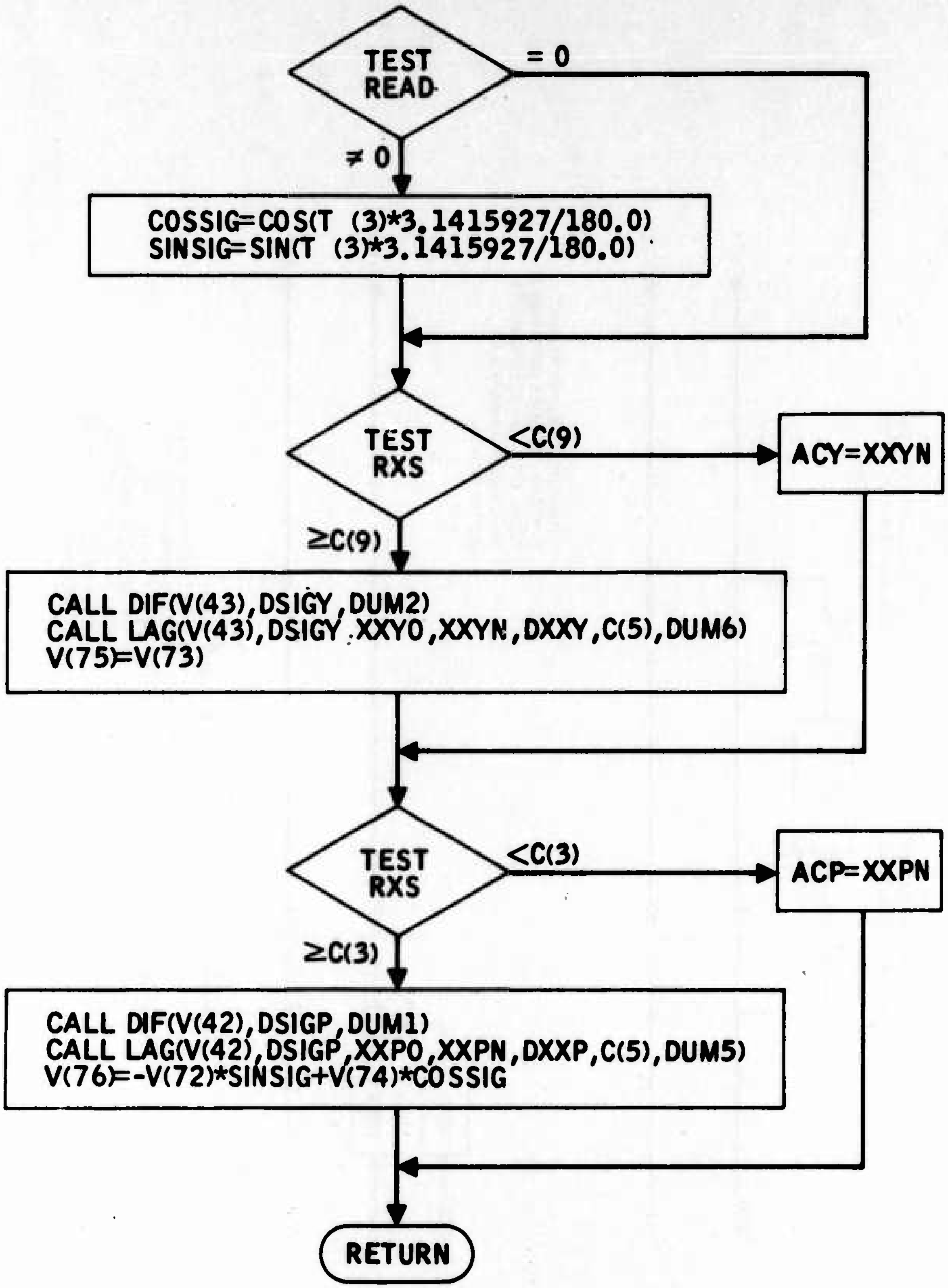


Figure 20. Subroutine BRF Flow Chart

2.3.8 Autopilot Subroutine (MPILOT)

(U) This subroutine simulates the behavior of the missile autopilot. It accepts inputs from the ARB and BRF subroutines as well as linear and angular acceleration components of the missile. Its outputs are the command control deflections in yaw, pitch and roll. A FORTRAN listing of this subroutine appears in Table XVIII. The corresponding flow chart and block diagram appear in Figure 21 and 22, respectively. A glossary of terms used in this subroutine appears in Table XIX.

2.3.9 Flipper Subroutine

(U) The Flipper subroutine simply accepts the outputs of the Autopilot subroutine and processes them to obtain the actual control surface deflections in the three control axes. The listing, block diagram, and flow chart are shown in Table XX and Figures 23 and 24, respectively. A glossary of terms appears in Table XXI.

2.3.10 Aerodynamic Subroutine

(U) The Aerodynamic (Aero) subroutine is the most complex of the entire program. The complete set of aerodynamic equations for forces and moments on the missile (as available from wind tunnel tests or actual flight tests) is programmed. Table XXII contains the subroutine listing, and Figure 25 is the block diagram of this portion of the simulation. A flow chart is shown in Figure 26, and a glossary of terms is contained in Table XXIII.

(U) The aerodynamic data is readily available only in maneuver axes; therefore, the force and moment coefficients are generated in these axes. Because of the complexity of the final equations of motion, the aerodynamic coefficients are generated in a series of steps which are labeled intermediate expressions, secondary expressions, and primary expressions; these steps are shown in sections (A), (B), and (C), respectively, of Table XXIV. It is desirable to integrate the equations of motion in missile coordinates; so the coefficient generates in maneuver axes are transformed to missile axes, as shown by the equations in Table XXV. The final six equations of motion in missile axes are shown in Table XXVI.

(U) This subroutine contains numerous parameters which are input as function generators and are used in the generation of the aerodynamic coefficients. This is achieved through curve fitting techniques applied to raw aerodynamic data. A separate list of the parameters contained in the function generators is supplied in Table XXVII.

(U) Among the options available in this subroutine are the selection of different values of missile mass and moments of inertia during several stages of thrusting. Three points in time are chosen (corresponding to the thrust interval) and corresponding values of mass and moments of inertia are also selected. During the portion of the simulation contained within this initial interval, the mass and moments of inertia are varied linearly between the selected values.

TABLE XVIII. AUTOPILOT SUBROUTINE FORTRAN LISTING

```
$        FORTRAN DECK
CPILC          MAVERICK AUTOPILOT                                                PIL00010
       SUBROUTINE MPILOT                                                         PIL00020
       COMMON /SSAM1/ READ,DELT,AUTOT,TIME
       COMMON /SSAM2/ V   (250),T   (250),C   (250)
       EQUIVALENCE                                                               PIL00050
     1 (V(12),WY      ),(V(13),WZ      ),(V(11),WX      ),(V(20),PHI    ),      PIL00060
     2 (V(42),ACP     ),(V(14),AX      ),(V(43),ACY     ),(V(2 ),DAC    ),      PIL00070
     3 (V(3 ),DPC     ),(V(4 ),DYC     )                                         PIL00080
       EQUIVALENCE                                                               PIL00090
     1 (V(60),AY      ),(V(61),AZ      ),(V(47),DDAC    ),(V(48),DDPC   ),      PIL00100
     2 (V(44),DWX     ),(V(45),DWY     ),(V(46),DWZ     ),(V(49),DDYC   )       PIL00110
       EQUIVALENCE                                                               PIL00120
     1(C(43),GSW   ),(C(44), AK    ),(C(45), BJ    ),(C(46),PHIJ  ),            PIL00130
     2(C(47),ACCLIM),(C(48),DIFLIM),(C(49),TYALD ),(C(50),TYALG ),              PIL00140
     3(C(51),TYPLD ),(C(52),TYDLG ),(C(53),DEADT ),(C(54),GHOLIM),              PIL00150
     4(C(55),TRCLG ),(C(56),RSW   ),(C(57),TAUACC),(C(58),TAURG ),              PIL00160
     5(C(59),DPHIJ ),(C(60),DALT  ),(C(61),TR1   ),(C(62),TR2   ),              PIL00170
     6(C(63),DAL1  ),(C(64),DAL2  ),(C(65),WGL   )                               PIL00180
C      C(43) THROUGH C(72) RESERVED FOR THIS SUBROUTINE                          PIL00190
       IF (READ.EQ.0.0) GO TO 50                                                 PIL00200
       CON=180.0/3.1415927                                                       PIL00210
       BK=CON*BJ                                                                 PIL00220
       PHIK=CON*PHIJ                                                             PIL00230
       DPHIK=DPHIJ*CON                                                           PIL00240
       YIN1=0.0                                                                  PIL00250
       PIN1=0.0                                                                  PIL00260
       PHIN=PHI                                                                  PIL00270
       PHIO=PHI                                                                  PIL00280
       DPHI=0.0                                                                  PIL00290
       ISW=0                                                                     PIL00300
       DAL=DAL1                                                                  PIL00310
       PHIO=T(6)/(TRCLG*CON)                                                     PIL00320
       PHIN=T(6)/(TRCLG*CON)                                                     PIL00330
       YIN30=0.                                                                  PIL00340
       WXL=0.0                                                                   PIL00350
       WXLO=0.0                                                                  PIL00360
       THETAX=0.0                                                                PIL00370
       THTAXN=0.0                                                                PIL00380
       DAC1=0.0                                                                  PIL00390
       AZN=0.0                                                                   PIL00400
       AZ1=0.0                                                                   PIL00410
       PIN2=0.0                                                                  PIL00420
       PIN20=0.0                                                                 PIL00430
       WYL=0.0                                                                   PIL00440
       WYLO=0.0                                                                  PIL00450
       PIN3=0.0                                                                  PIL00460
       PIN30=0.0                                                                 PIL00470
       AYN=0.0                                                                   PIL00480
       AY1=0.0                                                                   PIL00490
       YIN2=0.0                                                                  PIL00500
       YIN20=0.0                                                                 PIL00510
       WZL=0.0                                                                   PIL00520
       WZLO=0.0                                                                  PIL00530
       YIN3=0.0                                                                  PIL00540
       AZO=0.                                                                    PIL00550
       DUPIN=0.                                                                  PIL00560
       AYO=0.                                                                    PIL00570
       DUYIN=0.                                                                  PIL00580
       YIN30=0.                                                                  PIL00590
```

TABLE XVIII. AUTOPILOT SUBROUTINE FORTRAN LISTING (CONCLUDED)

```
      DM1=0.                                                            PIL00600
      DM2=0.                                                            PIL00610
      DM3=0.                                                            PIL00620
      DM4=0.                                                            PIL00630
      DM5=0.                                                            PIL00640
      DM6=0.                                                            PIL00650
      DM7=0.                                                            PIL00660
      DM8=0.                                                            PIL00670
      DM9=0.                                                            PIL00680
      DM10=0.                                                           PIL00690
      DM11=0.                                                           PIL00700
      DM12=0.                                                           PIL00710
      GO TO 65                                                          PIL00720
C                                                                       PIL00730
C     PITCH CONTROL                                                     PIL00740
   50 IF(ABS(WX).GE.RSW) ISW=1                                          PIL00750
      IF((AX.GT.GSW).OR.(TIME.LT.DEADT)) GO TO 65                       PIL00760
   60 CALL DIF(AZ,DAZZ,AZ0)                                             PIL00770
      CALL LAG(AZ,DAZZ,AZ1,AZN,DAZ,TAUACC,DM1)                          PIL00780
      CALL DIF(ACP,DACP,ACP0)                                           PILO 785
      CALL LIMIT(ACP,DACP,ACCLIM,-ACCLIM)                               PIL00790
      PIN1=AK*(ACP-AZ1)                                                 PIL00800
      CALL DIF (PIN1,DPIN,DDPIN)                                        PIL00810
      CALL LDLAG(PIN1,DPIN ,PIN20,PIN2,DPIN2,TYALD,TYALG,DM2)           PIL00820
      CALL LIMIT(PIN2,DPIN2,DIFLIM,-DIFLIM)                             PIL00830
      CALL LAG(WY,DWY,WYL0,WYL,DWYL,TAURG,DM3)                          PIL00840
      CALL LIMIT(WYL,DWYL,WGL,-WGL)                                     PIL00850
      CALL LDLAG(WYL0*BK,DWYL*BK,PIN30,PIN3,DPIN3,TYDLD,TYDLG,DM4)      PIL00860
C                                                                       PIL00870
C     YAW CONTROL                                                       PIL00880
      CALL DIF(AY,DAYY,AY0)                                             PIL00890
      CALL LAG(AY,DAYY,AY1,AYN,DAY,TAUACC,DM5)                          PIL00900
      CALL DIF(ACY,DACY,ACY0)                                           PILO 905
      CALL LIMIT(ACY,DACY,ACCLIM,-ACCLIM)                               PIL00910
      YIN1=AK*(AY1-ACY)                                                 PIL00920
      CALL DIF(YIN1,DYIN,DDYIN)                                         PIL00930
      CALL LDLAG(YIN1,DYIN ,YIN20,YIN2,DYIN2,TYALD,TYALG,DM6)           PIL00940
      CALL LIMIT(YIN2,DYIN2,DIFLIM,-DIFLIM)                             PIL00950
      CALL LAG(WZ,DWZ,WZL0,WZL,DWZL,TAURG,DM7)                          PIL00960
      CALL LIMIT(WZL,DWZL,WGL,-WGL)                                     PIL00970
      CALL LDLAG(WZL0*BK,DWZL*BK,YIN30,YIN3,DYIN3,TYDLD,TYDLG,DM8)      PIL00980
      DPC=PIN20+PIN30+YIN20                                             PIL00990
      DDPC=DPIN2+DPIN3+DYIN2                                            PIL01000
      DYC=YIN20+YIN30-PIN20                                             PIL01010
      DDYC=DYIN2+DYIN3-DPIN2                                            PIL01020
C                                                                       PIL01030
C     ROLL CONTROL                                                      PIL01040
   65 IF((TIME.LT.DEADT).AND.(ISW.EQ.0)) GO TO 100                      PIL01050
   70 CALL LAG(WX,DWX,WXL0,WXL,DWXL,TAURG,DM9)                          PIL01060
      CALL LIMIT(WXL,DWXL,GROLIM,-GROLIM)                               PIL01070
      CALL LAG( 0.0, 0.0,PHI0,PHIN,DPHI,TRCLG,DM10)                     PIL01080
      WX1=WXL0+PHI0+T(21)                                               PIL01090
      DWX1=DWXL+DPHI                                                    PIL01100
   90 CALL GRATE(1,WX1,DWX1,THETAX,TETAXN,DTAX,DM11)                    PIL01110
      RIN1=DPHIK*WX1+PHIK*THETAX                                        PIL01120
      DRIN1=DPHIK*DWX1+PHIK*DTAX                                        PIL01130
      CALL LDLAG(RIN1,DRIN1,DAC,DAC1,DDAC,TR1,TR2,DM12)                 PIL01140
      IF (TIME.GT.DALT) DAL=DAL2                                        PIL01150
      CALL LIMIT(DAC1,DDAC,DAL,-DAL)                                    PIL01160
  100 CALL DIF(AX,DAXX,DAXX0)                                           PIL01170
      CALL SPTEST(-AX,-DAXX,-GSW)                                       PIL01180
      CALL TTEST(DEADT)                                                 PIL01190
      CALL TTEST(DALT)                                                  PIL01200
      RETURN                                                            PIL01210
      END                                                               PIL01220
```

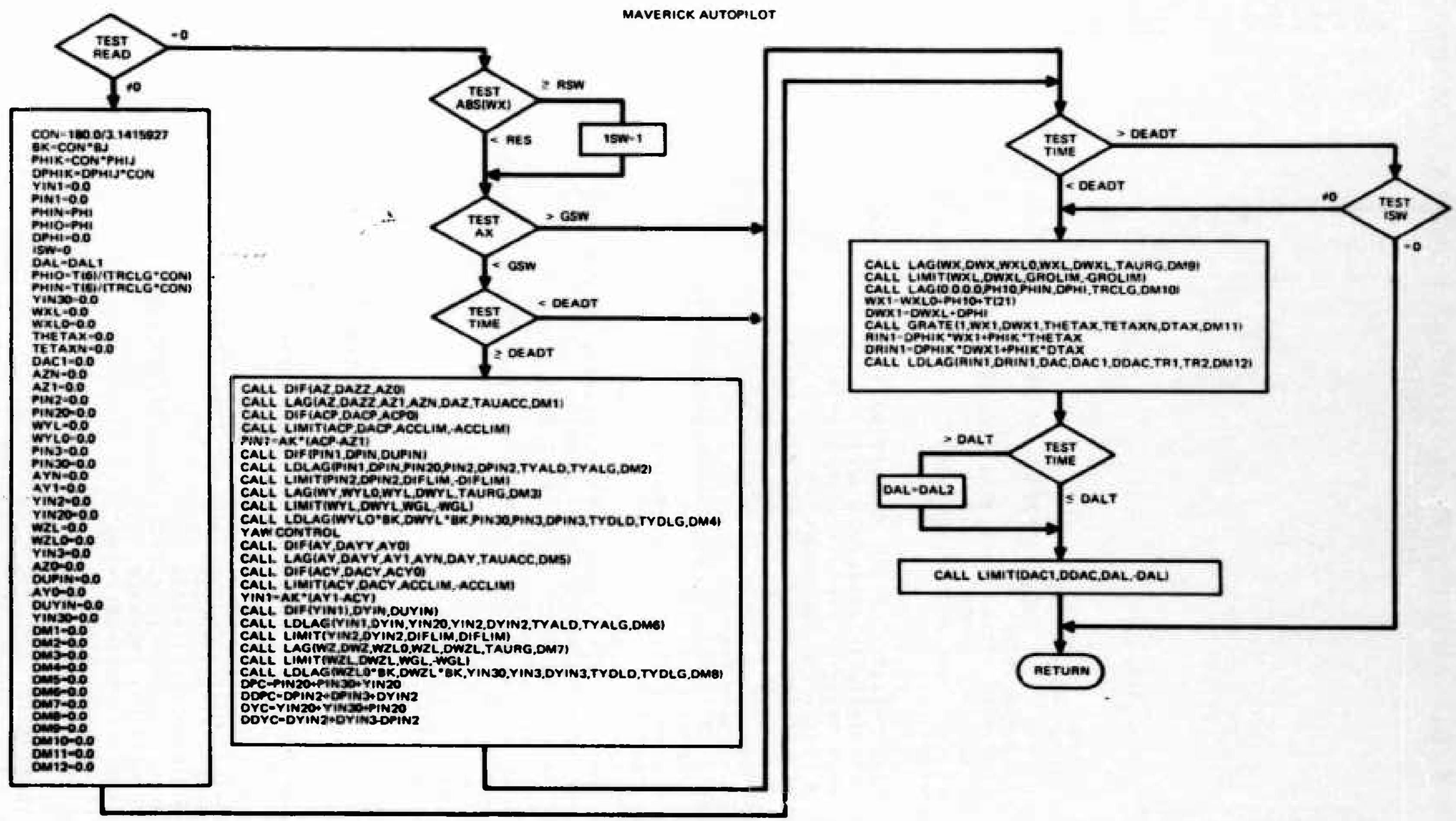


Figure 21. Autopilot Subroutine Flow Chart

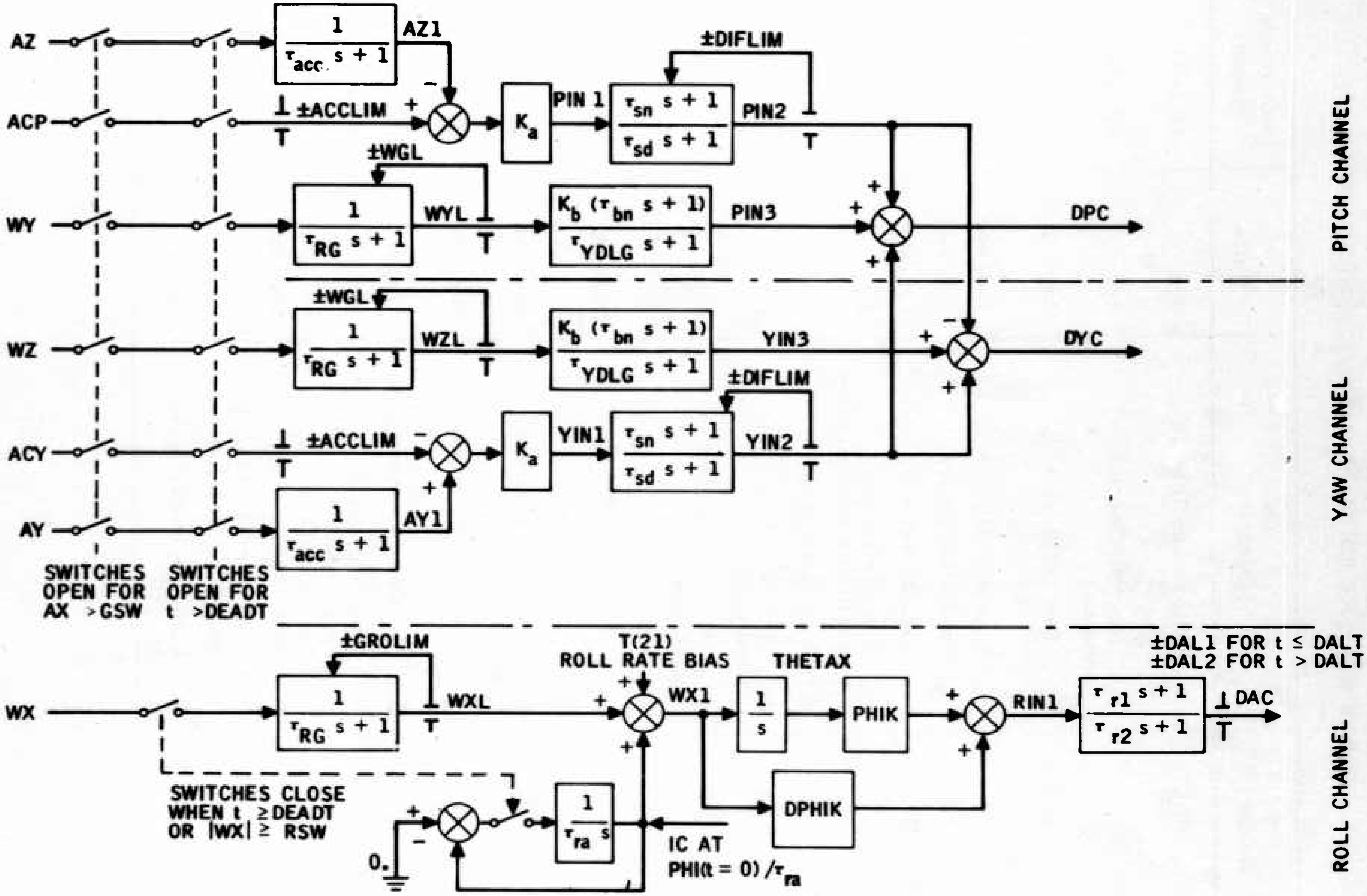


Figure 22. Autopilot Subroutine Block Diagram

TABLE XIX. AUTOPILOT (MPILOT) SUBROUTINE

Name	Quantity	Units	Coordinate System
V(2) DAC	δ_{ac}, Aileron deflection command	deg	Missile
V(3) DPC	δ_{pc}, Pitch deflection command	deg	Missile
V(4) DYC	δ_{yc}, Yaw deflection command	deg	Missile
V(11) WX	ω_x, Angular velocity	rad/sec	Missile
V(12) WY	ω_y, Anguiar velocity	rad/sec	Missile
V(13) WZ	ω_z, Angular velocity	rad/sec	Missile
V(14) AX	A_x, Propulsive and aerodynamic acceleration	g's	Missile
V(20) PHI	ϕ, Euler roll angle	rad	
V(42) ACP	A_{cp}, Acceleration command pitch	g's	Autopilot
V(43) ACY	A_{cy}, Acceleration command yaw	g's	Autopilot
V(44) DWX V(45) DWY V(46) DWZ	$\dot{\omega}_x$, $\dot{\omega}_y$, $\dot{\omega}_z$, Scalar, components of missile angular acceleration in autopilot axes	rad/sec^2	Missile
V(47) DDAC	$\dot{\delta}_{ac}$, Aileron command rate	deg/sec	Missile
V(48) DDPC	$\dot{\delta}_{pc}$, Elevator command rate	deg/sec	Missile
V(49) DDYC	$\dot{\delta}_{yc}$, Rudder command rate	deg/sec	Missile
V(60) AY	a_y missile lateral acceleration components	g's	Missile
V(61) AZ	a_z missile lateral acceleration components	g's	Missile
T(21)	Roll rate bias	rad/sec	Missile
C(43) GSW	Autopilot lateral channel activation switch level	g's	
C(44) AK	K_a, Lateral channel gain	deg/g	

TABLE XIX. AUTOPILOT (MPILOT) SUBROUTINE (CONCLUDED)

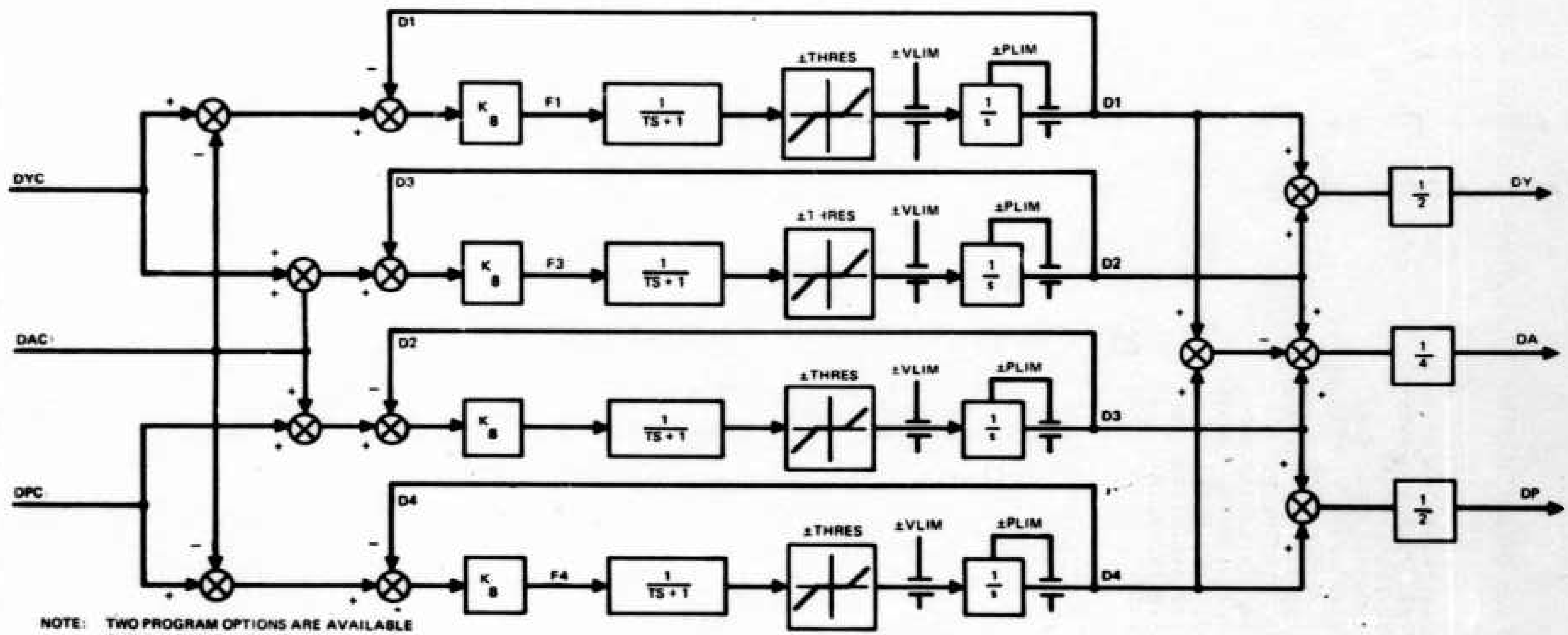
Name	Quantity	Units
C(45) BJ	K_b, Damping gain	deg/deg/sec
BK	K_b, Damping gain	deg/rad/sec
C(46) PHIJ	ϕ_k, Roll channel gain	deg/deg
PHIK	ϕ_k, Roll channel gain	deg/rad
C(47) ACCLIM	Acceleration limit, lateral channels	g's
C(48) DIFLIM	Command limit, lateral channels	deg
C(49) TYALD	τ_{sn}, Lead time constant	sec
C(50) TYALG	τ_{sd}, Lag time constant	sec
C(51) TYDLD	τ_{bn}, Lead time constant	sec
C(52) TYDLG	τ_{YDLG}, Lag time constant	sec
C(53) DEADT	Autopilot activation delay	sec
C(54) GROLIM	Roll rate signal limit	rad/sec
C(55) TRCLG	τ_{ra}	sec
C(56) RSW	Roll rate switch level	rad/sec
C(57) TAUACC	τ_{acc}, Lateral channel time constant	sec
C(58) TAURG	τ_{RG}, Lateral channel time constant	sec
C(59) DPHIJ	$\dot{\phi}_K$, Roll rate gain	deg/deg/sec
DPHIK	$\dot{\phi}_K$, Roll rate gain	deg/rad/sec
C(60) DALT	Roll channel limit change time	sec
C(61) TR1	τ_{r1}, Lead time constant	sec
C(62) TR2	τ_{r2}, Lag time constant	sec
C(63) DAL1	Roll command limit	deg
C(64) DAL2	Roll command limit	deg
C(65) WGL	Lateral channel rate limit	rad/sec

TABLE XX. FLIPPER SUBROUTINE FORTRAN LISTING

```
$      FORTRAN DECK
CFLIP        FLIPPER WITH THRESHOLD PROVISION                                  FLIP0010
      SUBROUTINE MFLIP                                                         FLIP0020
      COMMON /SSAM1/ READ,DELT,AUTOT,TIME
      COMMON /SSAM2/ V  (250),T  (250),C  (250)
      EQUIVALENCE                                                              FLIP0050
     1 (V( 2),DAC   ),(V(47),DDAC  ),(V( 3),DPC   ),(V(48),DDPC  ),            FLIP0060
     2 (V( 4),DYC   ),(V(49),DDYC  ),(V( 5),DA    ),(V( 6),DP    ),            FLIP0070
     3 (V( 7),DY    )                                                          FLIP0080
      EQUIVALENCE                                                              FLIP0090
     1 (C(97),GAIN  ),(C(98),TAU   ),(C(99),VLIM  ),(C(100),PLIM ),            FLIP0100
     2 (C(101),THRES)                                                          FLIP0110
      IF (READ.EQ.0.0) GO TO 10                                                FLIP0120
      D1=0.0                                                                   FLIP0130
      D2=0.0                                                                   FLIP0140
      D3=0.0                                                                   FLIP0150
      D4=0.0                                                                   FLIP0160
      DD1=0.0                                                                  FLIP0170
      DD2=0.0                                                                  FLIP0180
      DD3=0.0                                                                  FLIP0190
      DD4=0.0                                                                  FLIP0200
      TA1=1.0/GAIN                                                             FLIP0210
   10 IF (THRES.EQ.0.0) GO TO 15                                               FLIP0220
      F1=(DYC-DAC-D1)*GAIN                                                     FLIP0230
      DF1=(DDYC-DDAC-DD1)*GAIN                                                 FLIP0240
      F2=(DAC+DPC-D2)*GAIN                                                     FLIP0250
      DF2=(DDAC+DDPC-DD2)*GAIN                                                 FLIP0260
      F3=(DYC+DAC-D3)*GAIN                                                     FLIP0270
      DF3=(DDYC+DDAC-DD3)*GAIN                                                 FLIP0280
      F4=(DPC-DAC-D4)*GAIN                                                     FLIP0290
      DF4=(DDPC-DDAC-DD4)*GAIN                                                 FLIP0300
      GO TO 20                                                                 FLIP0310
   15 F1=DYC-DAC                                                               FLIP0320
      DF1=DDYC-DDAC                                                            FLIP0330
      F2=DAC+DPC                                                               FLIP0340
      DF2=DDAC+DDPC                                                            FLIP0350
      F3=DYC+DAC                                                               FLIP0360
      DF3=DDYC+DDAC                                                            FLIP0370
      F4=DPC-DAC                                                               FLIP0380
      DF4=DDPC-DDAC                                                            FLIP0390
      CALL   LAG(F1,DF1,D10,D1,DD1,TA1,DU1)                                    FLIP0400
      CALL  VLIMIT(D10,D1,DD1,VLIM,-VLIM)                                      FLIP0410
      CALL  LIMIT(D1,DD1,PLIM,-PLIM)                                           FLIP0420
      CALL   LAG(F2,DF2,D20,D2,DD2,TA1,DU2)                                    FLIP0430
      CALL  VLIMIT(D20,D2,DD2,VLIM,-VLIM)                                      FLIP0440
      CALL  LIMIT(D2,DD2,PLIM,-PLIM)                                           FLIP0450
      CALL   LAG(F3,DF3,D30,D3,DD3,TA1,DU3)                                    FLIP0460
      CALL  VLIMIT(D30,D3,DD3,VLIM,-VLIM)                                      FLIP0470
      CALL  LIMIT(D3,DD3,PLIM,-PLIM)                                           FLIP0480
      CALL   LAG(F4,DF4,D40,D4,DD4,TA1,DU4)                                    FLIP0490
      CALL  VLIMIT(D40,D4,DD4,VLIM,-VLIM)                                      FLIP0500
      CALL  LIMIT(D4,DD4,PLIM,-PLIM)                                           FLIP0510
      GO TO 30                                                                 FLIP0520
   20 CALL  LAG(F1,DF1,Z10,Z1,DZ,TAU,DU1)                                      FLIP0530
      CALL  DBAND(Z10,DZ,ZZ1,THRES,-THRES)                                     FLIP0540
      CALL  LIMIT(ZZ1,DZ1, VLIM,-VLIM)                                         FLIP0550
      CALL  GRATE(1,ZZ1,DZ1,D10,D1,DD1,DU2)                                    FLIP0560
      CALL  LIMIT (D1,DD1,PLIM,-PLIM)                                          FLIP0570
      CALL  LAG(F2,DF2,Z20,Z2,DZ,TAU,DU3)                                      FLIP0580
      CALL  DBAND(Z20,DZ,ZZ2,THRES,-THRES)                                     FLIP0590
```

TABLE XX. FLIPPER SUBROUTINE FORTRAN LISTING (CONCLUDED)

```
      CALL LIMIT(ZZ2,DZ,VLIM,-VLIM)                                    FLIP0600
      CALL GRATE(1,ZZ2,DZ,D20,D2,DD2,DU4)                              FLIP0610
      CALL LIMIT (D2,DD2,PLIM,-PLIM)                                   FLIP0620
      CALL LAG(F3,DF3,Z30,Z3,DZ,TAU,DU5)                               FLIP0630
      CALL DBAND(Z30,DZ,ZZ3,THRES,-THRES)                              FLIP0640
      CALL LIMIT(ZZ3,DZ,VLIM,-VLIM)                                    FLIP0650
      CALL GRATE(1,ZZ3,DZ,D30,D3,DD3,DU6)                              FLIP0660
      CALL LIMIT(D3,DD3,PLIM,-PLIM)                                    FLIP0670
      CALL LAG(F4,DF4,Z40,Z4,DZ,TAU,DU7)                               FLIP0680
      CALL DBAND(Z40,DZ,ZZ4,THRES,-THRES)                              FLIP0690
      CALL LIMIT(ZZ4,DZ,VLIM,-VLIM)                                    FLIP0700
      CALL GRATE(1,ZZ4,DZ,D40,D4,DD4,DU8)                              FLIP0710
      CALL LIMIT(D4,DD4,PLIM,-PLIM)                                    FLIP0720
   30 DA=.25*(D2-D4-D1+D3)                                             FLIP0730
      DP=.5*(D2+D4)                                                    FLIP0740
      DY=.5*(D1+D3)                                                    FLIP0750
      RETURN                                                           FLIP0760
      END                                                              FLIP0770
```



NOTE: TWO PROGRAM OPTIONS ARE AVAILABLE WITH AND WITHOUT THRESHOLD. WHEN THRESHOLD IS NOT USED A DIFFERENT PROGRAMMING TECHNIUQE IS EMPLOYED IN THE INTEREST OF EFFICIENCY.

Figure 23. Flipper Subroutine Block Diagram

FLIPPER WITH THRESHOLD PROVISION

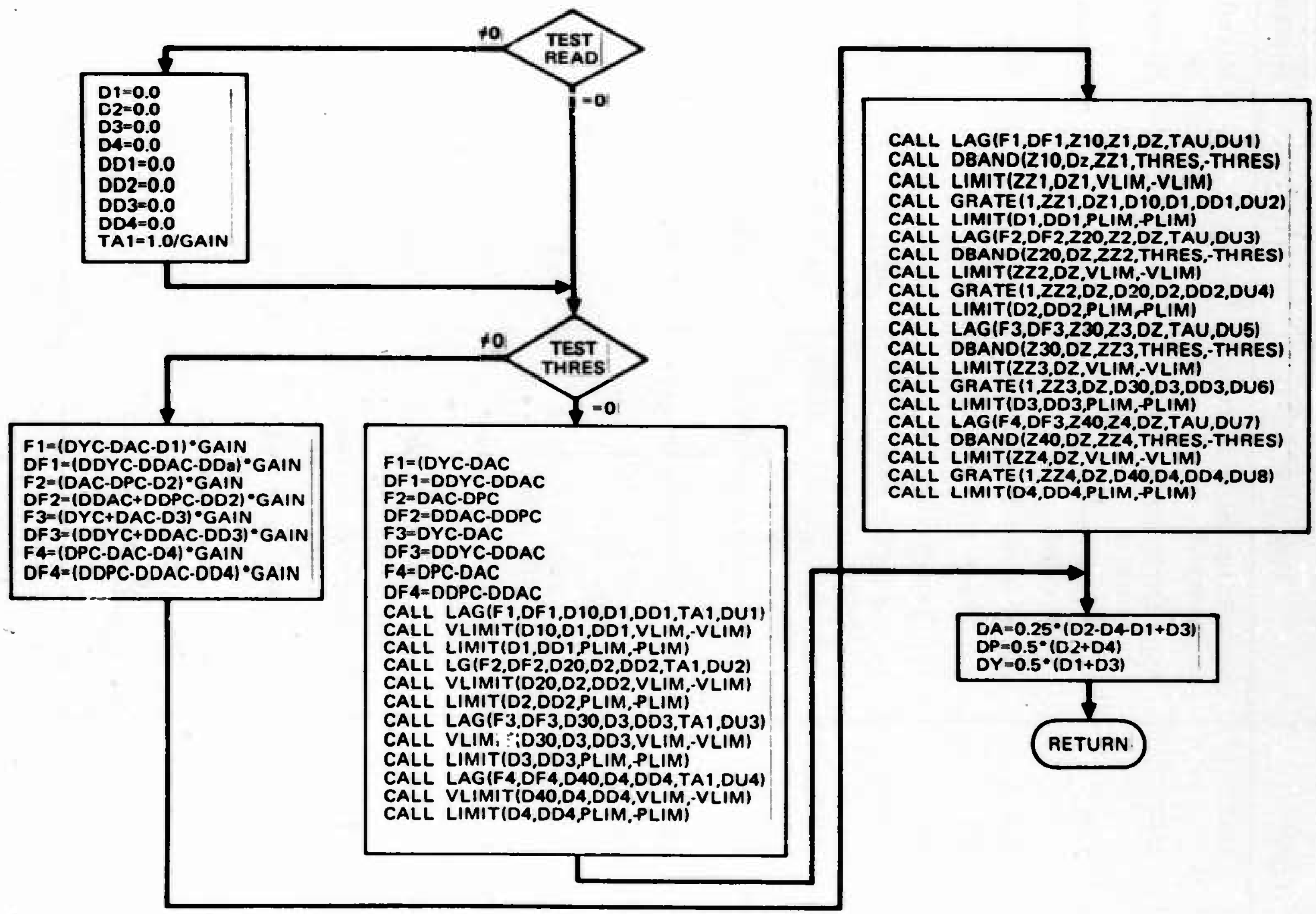


Figure 24. Flipper Subroutine Flow Chart

TABLE XXI. FLIPPER (MFLIP) SUBROUTINE

Name		Quantity	Units	Coordinate System
V(2)	DAC	δ_{ac}, Aileron deflection command	deg	Missile
V(3)	DPC	δ_{pc}, Pitch deflection command	deg	Missile
V(4)	DYC	δ_{yc}, Yaw deflection command	deg	Missile
V(5)	DA	δ_a, Aileron deflection	deg	Missile
V(6)	DP	δ_p, Pitch deflection	deg	Missile
V(7)	DY	δ_y, Yaw deflection	deg	Missile
V(47)	DDAC	$\dot{\delta}_{ac}$, Aileron command rate	deg/sec	Missile
V(48)	DDPC	$\dot{\delta}_{pc}$, Elevator command rate	deg/sec	Missile
V(49)	DDYC	$\dot{\delta}_{yc}$, Rudder command rate	deg/sec	Missile
C(97)	GAIN	K_δ, Servo velocity gain	1/sec	
C(98)	TAU	τ_δ, Control surface time constant	sec	
C(99)	VLIM	$\dot{\delta}_L$, Control surface velocity limit	deg/sec	
C(100)	PLIM	δ_L, Control surface angle limit	deg	
C(101)	THRES	δ_{th}, Control surface rate threshold	deg/sec	
	D1	δ_1, Control surface No. 1 deflection	deg	
	D2	δ_2, Control surface No. 2 deflection	deg	
	D3	δ_3, Control surface No. 3 deflection	deg	
	D4	δ_4, Control surface No. 4 deflection	deg	

TABLE XXII. AERO SUBROUTINE FORTRAN LISTING

```
$      FORTRAN DECK
CMAERO         MAVERICK AERO                                                  AERO0010
       SUBROUTINE MAERO                                                       AERO0020
       COMMON /SSAM1/ READ,DELT,AUTOT,TIM                                     AERO   30
       COMMON /SSAM2/ V   (250),T   (250),C   (250)
       EQUIVALENCE                                                            AERO0050
     1 (V( 1),RELALT),(V( 5),DA     ),(V( 6),DP     ),(V( 7),DY     ),        AERO0060
     2 (V( 8),VXM    ),(V( 9),VYM   ),(V(10),VZM    ),(V(11),WX     ),        AERO0070
     3 (V(12),WY     ),(V(13),WZ    ),(V(14),AX     ),(V(15),AY     ),        AERO0080
     4 (V(16),AZ     ),(V(33),ALPHA ),(V(34),ALPHAP),(V(35),ALPHAY)           AERO0090
       EQUIVALENCE                                                            AERO0100
     2 (V(45),DWY    ),(V(46),DWZ   ),(V(39),Q      ),(V(40),VM     ),        AERO0110
     3 (V(41),AM     ),(V(44),DWX   ),(V(84),CAPLAM)                          AERO0120
       EQUIVALENCE                                                            AERO0130
     1(C(73),S      ),(C(74),D      ),(C(75),FSL    ),(C(76),TBOOST),         AERO0140
     2(C(77),TSUST  ),(C(78),ELTB   ),(C(79),XBAR   ),(C(80),CLP    ),        AERO0150
     3(C(81),AE     ),(C(82),AJX0   ),(C(83),AJX1   ),(C(84),AJXT   ),        AERO0160
     4(C(85),AJY0   ),(C(86),AJY1   ),(C(87),AJYT   ),(C(88),AMASS0),         AERO0170
     5(C(89),AMASS1),(C(90),AMASST)                                           AERO0180
     6,(C(91),TSEPAR),(C(92),TGTALT)                                          AERO0190
       DATA RD2/114.59156/                                                    AERO0200
       DATA RTOD/57.29578/                                                    AERO0210
       IF (READ.EQ.0.0) GO TO 5                                               AERO0220
       FLUB=1.414213/(32.2*57.29578)                                          AERO0230
       SD = S*D                                                               AERO0240
       G=32.2                                                                 AERO0250
       DOV2=D/2.0                                                             AERO0260
       RXB=RD2*(XBAR/D)**2                                                    AERO0270
       AEOS=AE/S                                                              AERO0280
       CONALF=2.0*XBAR**2/(3.0*D**2)                                          AERO0290
       DOLTB=D/ELTB                                                           AERO0300
       DAJX1=(AJX0-AJX1)/TBOOST                                               AERO0310
       DAJY1=(AJY0-AJY1)/TBOOST                                               AERO0320
       DMASS=(AMASS0-AMASS1)/TBOOST                                           AERO0330
       TDIF=TSUST-TBOOST                                                      AERO0340
       DAJX2=(AJX1-AJXT)/TDIF                                                 AERO0350
       DAJY2=(AJY1-AJYT)/TDIF                                                 AERO0360
       DMASS2=(AMASS1-AMASST)/TDIF                                            AERO0370
     5 VYZ2=VYM**2+VZM**2                                                     AERO0380
       VYZ=SQRT(VYZ2)                                                         AERO0390
       VSQ=VYZ2+VXM**2                                                        AERO0400
       VM=SQRT(VSQ)                                                           AERO0410
       TIME=TIM+TSEPAR                                                        AERO0420
       ALT=RELALT+TGTALT                                                      AERO0425
C                                                                             AERO0430
C  MACH NUMBER                                                                AERO0440
       CALL FGEN1(I1,ALT,SVEL,-1)                                             AERO045
       AM=VM/SVEL                                                             AERO0460
C                                                                             AERO0470
C  AERODYNAMIC ROLL ANGLE, PHIA                                               AERO0480
       IF (VYZ.NE.0.0) GO TO 10                                               AERO0490
       CPHIA=.70711                                                           AERO0500
       SPHIA=.70711                                                           AERO0510
       GO TO 20                                                               AERO0520
    10 CPHIA=VZM/VYZ                                                          AERO0530
       SPHIA=VYM/VYZ                                                          AERO0540
C                                                                             AERO0550
C  ANGLE OF ATTACK, ALPHA                                                     AERO0560
    20 ALPHA=ATAN(VYZ/VXM)*RTOD                                               AERO0570
       ALPHA2=ALPHA**2                                                        AERO0580
```

```
      ALPHA3=ALPHA2*ALPHA
      ALPHAP=ALPHA*CPHIA
      ALPHAY=ALPHA*SPHIA
      CALL DIF(ALPHAP,DALFP,DALFP1)
      CALL DIF(ALPHAY,DALFY,DALFY1)
C
C  FLIPPER DEFLECTIONS IN MANEUVER AXES
      DT=DP*CPHIA-DY*SPHIA
      DR=DY*CPHIA+DP*SPHIA
C
C  AUXILIARY FUNCTIONS
      COS4PH=1.0-6.0*CPHIA**2*SPHIA**2
      SIN4PH=5.18*(ABS(CPHIA)-ABS(SPHIA))*CPHIA*SPHIA
      DD2V=DOV2/VM
C
C  MANEUVER AXES AERODYNAMIC COEFFICIENTS
C     *****************************
C  INTERMEDIATE EXPRESSIONS
C  C SUB SMALL MO
      N=0
      CALL FGEN1(I2,AM,SM1,N)
      CALL FGEN1(I3,AM,SM2,N)
      CALL FGEN1(I4,AM,SM3,N)
      CALL FGEN1(I5,AM,SM4,N)
      CSMO=SM1*ALPHA+(SM2+SM3*COS4PH)*ALPHA2 + SM4*ALPHA3
C
C  DELTA C SUM SMALL M
      CALL FGEN1(I6,AM,SM5,N)
      CALL FGEN1(I7,AM,SM6,N,
      CALL FGEN1(I8,AM,SM7,N)
      DCSM= (SM5+(SM6 + SM7*COS4PH)*ALPHA2)*DT
C
C  C SUB SMALL NO
      CALL FGEN1(I9,AM,SN1,N)
      CALL FGEN1(I10,AM,SN2,N)
      CSNO=(SN1*ALPHA2 + SN2*ALPHA3)*SIN4PH
C
C  DELTA C SUB SMALL N
      CALL FGEN1(I11,AM,SN3,N)
      CALL FGEN1(I12,AM,SN4,N)
      CALL FGEN1(I13,AM,SN5,N)
      CALL FGEN1(I14,AM,SN6,N)
      CALL FGEN1(I15,AM,SN7,N)
      CALL FGEN1(I16,AM,SN8,N)
      DCSN=(SN3 + (SN4 + SN5*COS4PH)*ALPHA2)*DR
     1 + ((SN6 + SN7*COS4PH)*ALPHA + SN8*ALPHA2*DT)*DA
C
C  C SUB NO
      CALL FGEN1(I17,AM,CN1,N)
      CALL FGEN1(I18,AM,CN2,N)
      CALL FGEN1(I19,AM,CN3,N)
      CALL FGEN1(I20,AM,CN4,N)
      CNO=CN1*ALPHA + (CN2+CN3*COS4PH)*ALPHA2 + CN4*ALPHA3
C
C  DELTA C SUB N
      DCN=DOLTB*DCSM
C
C  C SUB YO
      CALL FGEN1(I21,AM,Y1,N)
      CALL FGEN1(I22,AM,Y2,N)
```

```
      CYO=(Y1*ALPHA2 + Y2*ALPHA3)*SIN4PH                                AERO1190
C                                                                       AERO1200
C  DELTA C SUB Y                                                        AERO1210
      DCY=DULTB*DCSN                                                    AERO1220
C                                                                       AERO1230
C  C SUB CO                                                             AERO1240
      CALL FGEN1(123,AM,CDW,N)                                          AERO1250
      CALL FGEN1(124,AM,C2,N)                                           AERO126
      CALL FGEN1(125,AM,C3,N)                                           AERO127
      CALL FGEN1(127,AM,CDF1,N)                                         AERO128
      CALL FGEN1(128,AM,CDF2,N)                                         AERO129
      IF((TIME.GT.TSUST ).AND.(READ.EQ.0.0))GO TO 30                    AERO1300
      CALL FGEN1(126,AM,CDB,N)                                          AERO1310
      GO TO 40                                                          AERO1320
   30 CDB=0.0                                                           AERO1330
   40 CDF=ALT*(CDF1 + ALT*CDF2)                                         AERO1340
      C1=CDW + CDF + CDB*AEOS                                           AERO1350
      CCO=C1+C2*ALPHA+C3*ALPHA2                                         AERO1360
C                                                                       AERO1370
C  DELTA C SUB  C                                                       AERO1380
      CALL FGEN1(130,AM,C4,N)                                           AERO1390
      CALL FGEN1(131,AM,C5,N)                                           AERO1400
      DCC=C4*(ALPHAP*UP-ALPHAY*DY)+C5*DT**2                             AERO1410
C                                                                       AERO1420
C  C SUB LO                                                             AERO1430
      CALL FGEN1(132,AM,SL1,N)                                          AERO1440
      CALL FGEN1(133,AM,SL2,N)                                          AERO1450
      CALL FGEN1(134,AM,SL3,N)                                          AERO1460
      CALL FGEN1(135,AM,SL4,N)                                          AERO1470
      CALL FGEN1(136,AM,SL5,N)                                          AERO1480
      CALL FGEN1(137,AM,SL6,N)                                          AERO1490
      CALL FGEN1(138,AM,SL7,N)                                          AERO1500
      CALL FGEN1(139,AM,SL8,N)                                          AERO1510
      CALL FGEN1(140,AM,SL9,N)                                          AERO1520
      CALL FGEN1(140,AM,SL10,N)                                         AERO153
      CLO=(SL1 +SL2*ALPHA + SL3*ALPHA2 + SL4*ALPHA3)*ALPHA2*SIN4PH      AERO1540
C                                                                       AERO1550
C  DELTA C SUB L                                                        AERO1560
      DCL=(SL5+(SL6+SL7*COS4PH)*ALPHA )*DA+(SL8*ALPHA+(SL9+SL10*COS4PH) AERO1570
     1*ALPHA2)*DR                                                       AERO1580
      IF ((TIME.GT.TSUST).AND.(READ.EQ.0.0)) GO TO 50                   AERO1590
      IF (TIME.GT.TBOOST) GO TO 45                                      AERO1600
      AMASS=AMASS0-DMASS*TIME                                           AERO1610
      AJY=AJY0-DAJY1*TIME                                               AERO1620
      AJX=AJX0-DAJX1*TIME                                               AERO1630
      GO TO 46                                                          AERO1640
   45 TDIF=TIME-TBOOST                                                  AERO1650
      AMASS=AMASS1-DMASS2*TDIF                                          AERO1660
      AJY=AJY1-DAJY2*TDIF                                               AERO1670
      AJX=AJX1-DAJX2*TDIF                                               AERO1680
   46 AJXY=(AJY-AJX)/AJY                                                AERO1690
C  1.0 - DELTA L/LTH                                                    AERO1710
      CALL FGEN1(141,TIME,DLOD,-1)                                      AERO1700
      CALL FGEN1(142,TIME,OMDLOL,-1)                                    AERO1720
      CALL FGEN1(144,TIME,THRUST,-1)                                    AERO1730
      CALL FGEN1(145,ALT,PRES,-1)                                       AERO1740
      TOM=(THRUST +AE*(PSL-PRES))/AMASS                                 AERO1750
      GO TO 60                                                          AERO1760
   50 TOM=0.0                                                           AERO1770
   60 CALL FGEN1(143,ALT,RHO,-1)                                        AERO1780
```

TABLE XXII. AERO SUBROUTINE FORTRAN LISTING (CONTINUED)

```
C
C  PRIMARY EXPRESSIONS
      CSUBM=CSMO-DLOD*CNO+OMDLOL*DCSM
      CSLCN=CSNO+DLOD*CYO+OMDLOL*DCSN
      CSUBN=CNO+DCN
      CSUBY=CYO-DCY
      CSUBC=CCO+DCC
      CSUBL=CLO + DCL
      CNDALP=CN1+ALPHA*(CN2+CN3*COS4PH+ALPHA*CN4)
      CMQ=RXB*CNDALP
      CMDALF=DO2V*CONALF*CMQALP
C
C
C  AERODYNAMIC COEFFICIENTS IN MISSILE AXES
      CSUBMB=CSUBM*CPHIA+CSLCN*SPHIA
     1 + CMDALF*DALFP
      CSLCNB=CSLCN*CPHIA-CSUBM*SPHIA
     1 - CMDALF * DALFY
      CSUBNB=CSUBN*CPHIA -CSUBY*SPHIA
      CSUBYB=CSUBY*CPHIA +CSUBN*SPHIA
C  DYNAMIC PRESSURE, Q
      Q=RHO*VSQ/2.0
C
C  ACCELERATIONS
      CON1 = Q*S/AMASS
      CON2 = Q*SD/AJX
      CON3 = Q*SD/AJY
      COX=-DO2V*CLP
      COYZ=-DO2V*CMQ
      TAUX=1.0/(COX*CON2)
      TAUZ =1.0/(COYZ*CON3)
      TS=WX*AJXY*TAUZ
      AXM=CON1*CSUBC + TOM
      AYM=CON1*CSUBYB
      AZM=CON1*CSUBNB
      CALL EULTRN(0,-1,0.0,0.0,0.0,GX,GY,GZ,YAW,ROLL,PITCH)
      CALL R45F(GX,GY,GZ,GXM,GYM,GZM)
C
      TX=CSUBL/COX
      CALL DIF(TX,DTX,DX1)
      TY=CSUBMB/COYZ+TS*WZ
      CALL DIF(TY,DTY,DY1)
      TZ=CSLCNB/COYZ-TS*WY
      CALL DIF(TZ,DTZ,DZ1)
      IF(READ .EQ. 0.0)GO TO 70
      TX = WX
      TY = WY
      TZ = WZ
      DTX = 0.0
      DTY = 0.0
      DTZ = 0.0
   70 DVX=AXM+GXM+WZ*VYM-WY*VZM
      DVY=AYM+GYM+WX*VZM-WZ*VXM
      DVZ=AZM+GZM+WY*VXM-WX*VYM
      CALL INTER(DVX,XX1,XX2,VXO,VXM)
      CALL INTER(DVY,YY1,YY2,VYO,VYM)
      CALL INTER(DVZ,ZZ1,ZZ2,VZO,VZM)
      CALL LAG (TX,DTX,WXO,WX,DWX,TAUX,DUMX)
      CALL LAG (TY,DTY,WYO,WY,DWY,TAUZ,DUMY)
      CALL LAG (TZ,DTZ,WZO,WZ,DWZ,TAUZ,DUMZ)
```

TABLE XXII. AERO SUBROUTINE FORTRAN LISTING (CONCLUDED)

```
      AX=AXM/G
      AY=AYM/G
      AZ=AZM/G
      ZAP1=C(44)*C(14)*1.414213
      ZAP2=C(44)*V(40)*FLUR
      ZAP3=2.*AMASS/(RHO*V(40)*S)
      ZAP4=(CN1+(CN2+CN3*COS4PH)*ALPHA+CN4*ALPHA2)/(SM1+(SM2+SM3*COS4PH)
     1     *ALPHA+SM4*ALPHA2)-DOLTB
      ZAP5=SM5+(SM6+SM7*COS4PH)*ALPHA2
      CAPLAM = ZAP1/(ZAP2+C(45)-ZAP3/(ZAP4*ZAP5*57.295787))
      RETURN
      END
```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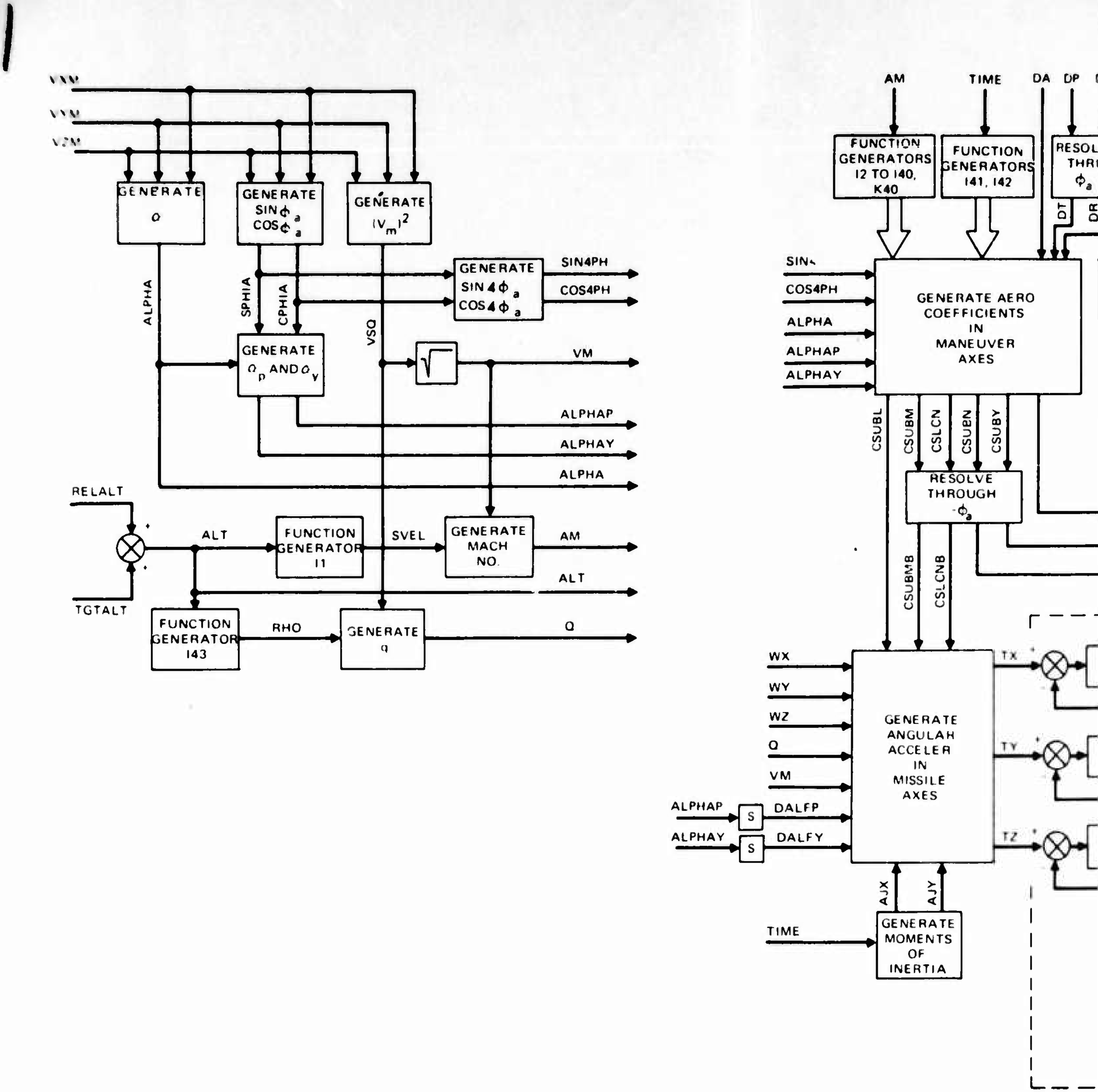

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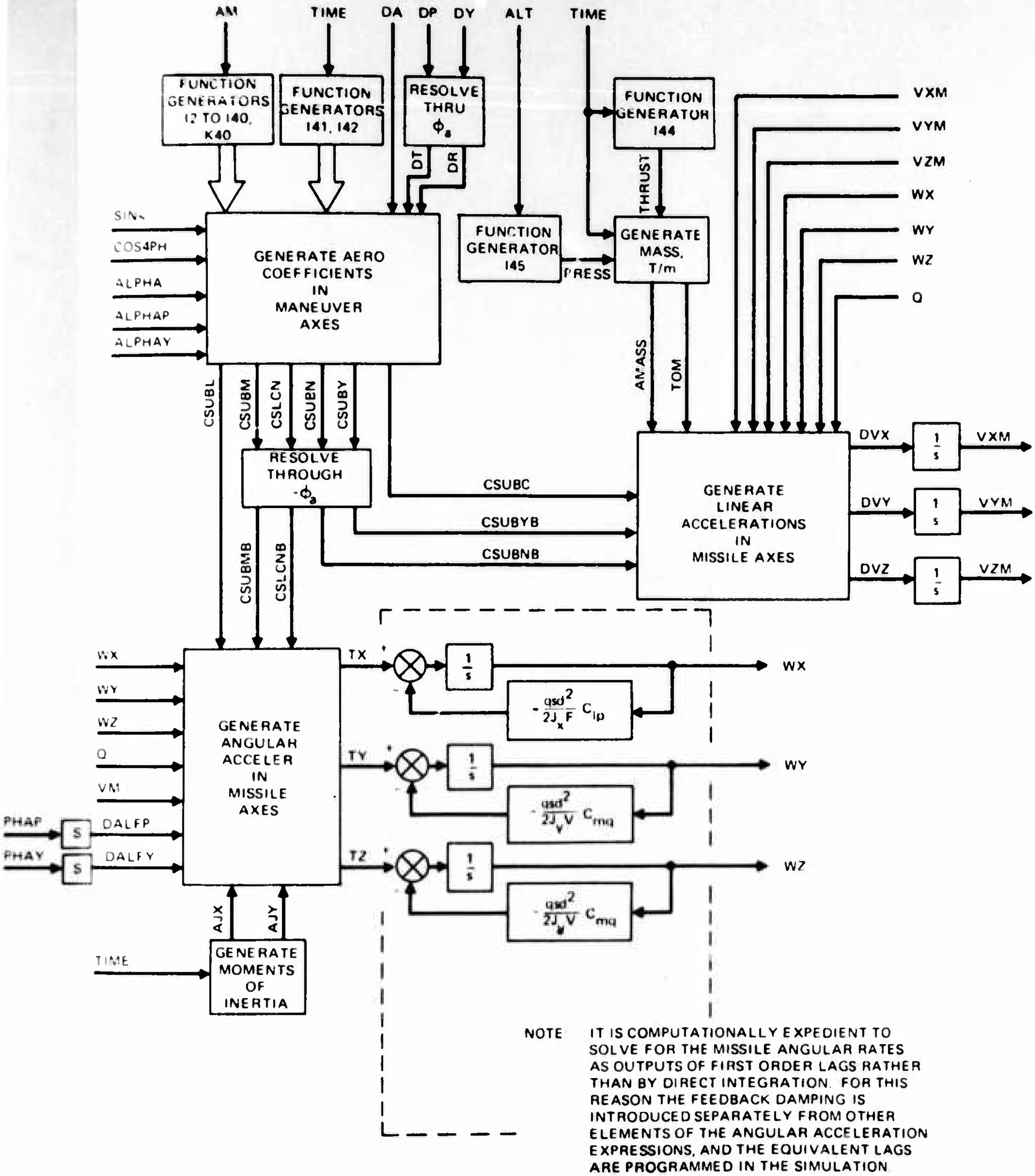

Figure 25. Aero Subroutine
Block Diagram

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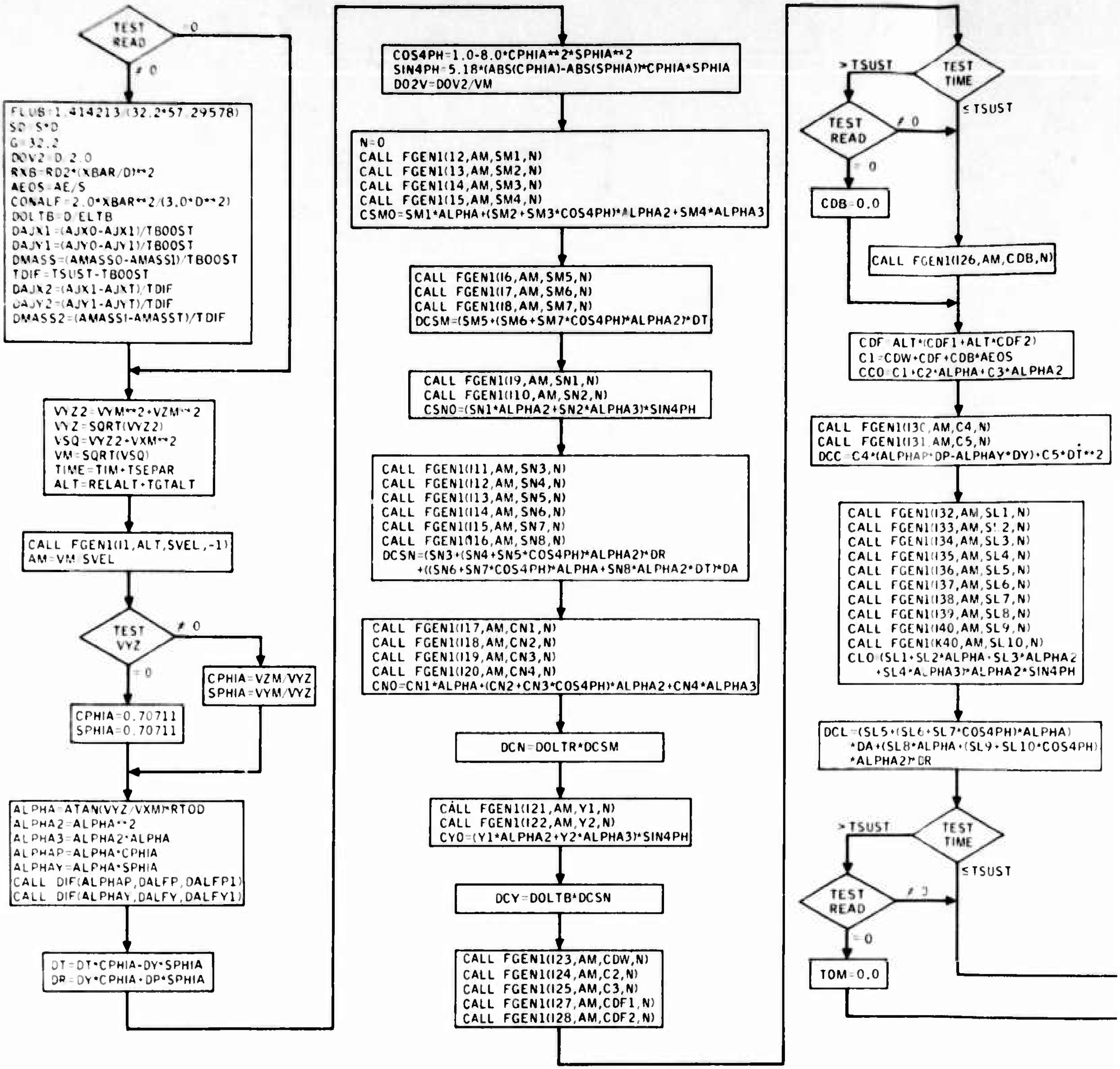
TEST READ
=0
≠0
FLUB=1.414213/(32.2*57.29578)
SD=S*D
G=32.2
DOV2=D/2.0
RXB=RD2*(XBAR/D)**2
AEOS=AE/S
CONALF=2.0*XBAR**2/(3.0*D**2)
DOLTB=D/ELTB
DAJX1=(AJX0-AJX1)/TBOOST
DAJY1=(AJY0-AJY1)/TBOOST
DMASS=(AMASS0-AMASS1)/TBOOST
TDIF=TSUST-TBOOST
DAJX2=(AJX1-AJXT)/TDIF
DAJY2=(AJY1-AJYT)/TDIF
DMASS2=(AMASS1-AMASST)/TDIF
VYZ2=VYM**2+VZM**2
VYZ=SQRT(VYZ2)
VSQ=VYZ2+VXM**2
VM=SQRT(VSQ)
TIME=TIM+TSEPAR
ALT=RELALT+TGTALT
CALL FGEN1(I1,ALT,SVEL,-1)
AM=VM/SVEL
TEST VYZ
≠0
=0
CPHIA=VZM/VYZ
SPHIA=VYM/VYZ
CPHIA=0.70711
SPHIA=0.70711
ALPHA=ATAN(VYZ/VXM)*RTOD
ALPHA2=ALPHA**2
ALPHA3=ALPHA2*ALPHA
ALPHAP=ALPHA*CPHIA
ALPHAY=ALPHA*SPHIA
CALL DIF(ALPHAP,DALFP,DALFP1)
CALL DIF(ALPHAY,DALFY,DALFY1)
DT=DT*CPHIA-DY*SPHIA
DR=DY*CPHIA+DP*SPHIA
COS4PH=1.0-8.0*CPHIA**2*SPHIA**2
SIN4PH=5.18*(ABS(CPHIA)-ABS(SPHIA))*CPHIA*SPHIA
DO2V=DOV2/VM
N=0
CALL FGEN1(12,AM,SM1,N)
CALL FGEN1(13,AM,SM2,N)
CALL FGEN1(14,AM,SM3,N)
CALL FGEN1(15,AM,SM4,N)
CSMO=SM1*ALPHA+(SM2+SM3*COS4PH)*ALPHA2+SM4*ALPHA3
CALL FGEN1(I6,AM,SM5,N)
CALL FGEN1(I7,AM,SM6,N)
CALL FGEN1(I8,AM,SM7,N)
DCSM=(SM5+(SM6+SM7*COS4PH)*ALPHA2)*DT
CALL FGEN1(I9,AM,SN1,N)
CALL FGEN1(I10,AM,SN2,N)
CSNO=(SN1*ALPHA2+SN2*ALPHA3)*SIN4PH
CALL FGEN1(I11,AM,SN3,N)
CALL FGEN1(I12,AM,SN4,N)
CALL FGEN1(I13,AM,SN5,N)
CALL FGEN1(I14,AM,SN6,N)
CALL FGEN1(I15,AM,SN7,N)
CALL FGEN1(I16,AM,SN8,N)
DCSN=(SN3+(SN4+SN5*COS4PH)*ALPHA2)*DR
+((SN6+SN7*COS4PH)*ALPHA+SN8*ALPHA2*DT)*DA
CALL FGEN1(I17,AM,CN1,N)
CALL FGEN1(I18,AM,CN2,N)
CALL FGEN1(I19,AM,CN3,N)
CALL FGEN1(I20,AM,CN4,N)
CNO=CN1*ALPHA+(CN2+CN3*COS4PH)*ALPHA2+CN4*ALPHA3
DCN=DOLTR*DCSM
CALL FGEN1(I21,AM,Y1,N)
CALL FGEN1(I22,AM,Y2,N)
CYO=(Y1*ALPHA2+Y2*ALPHA3)*SIN4PH
DCY=DOLTB*DCSN
CALL FGEN1(I23,AM,CDW,N)
CALL FGEN1(I24,AM,C2,N)
CALL FGEN1(I25,AM,C3,N)
CALL FGEN1(I27,AM,CDF1,N)
CALL FGEN1(I28,AM,CDF2,N)
TEST TIME
>TSUST
≤TSUST
TEST READ
≠0
=0
CDB=0.0
CALL FGEN1(I26,AM,CDB,N)
CDF=ALT*(CDF1+ALT*CDF2)
C1=CDW+CDF+CDB*AEOS
CCO=C1+C2*ALPHA+C3*ALPHA2
CALL FGEN1(I30,AM,C4,N)
CALL FGEN1(I31,AM,C5,N)
DCC=C4*(ALPHAP*DP-ALPHAY*DY)+C5*DT**2
CALL FGEN1(I32,AM,SL1,N)
CALL FGEN1(I33,AM,SL2,N)
CALL FGEN1(I34,AM,SL3,N)
CALL FGEN1(I35,AM,SL4,N)
CALL FGEN1(I36,AM,SL5,N)
CALL FGEN1(I37,AM,SL6,N)
CALL FGEN1(I38,AM,SL7,N)
CALL FGEN1(I39,AM,SL8,N)
CALL FGEN1(I40,AM,SL9,N)
CALL FGEN1(K40,AM,SL10,N)
CLO=(SL1+SL2*ALPHA+SL3*ALPHA2
+SL4*ALPHA3)*ALPHA2*SIN4PH
DCL=(SL5+(SL6+SL7*COS4PH)*ALPHA)
*DA+(SL8*ALPHA+(SL9+SL10*COS4PH)
*ALPHA2)*DR
TEST TIME
>TSUST
≤TSUST
TEST READ
≠0
=0
TOM=0.0

2

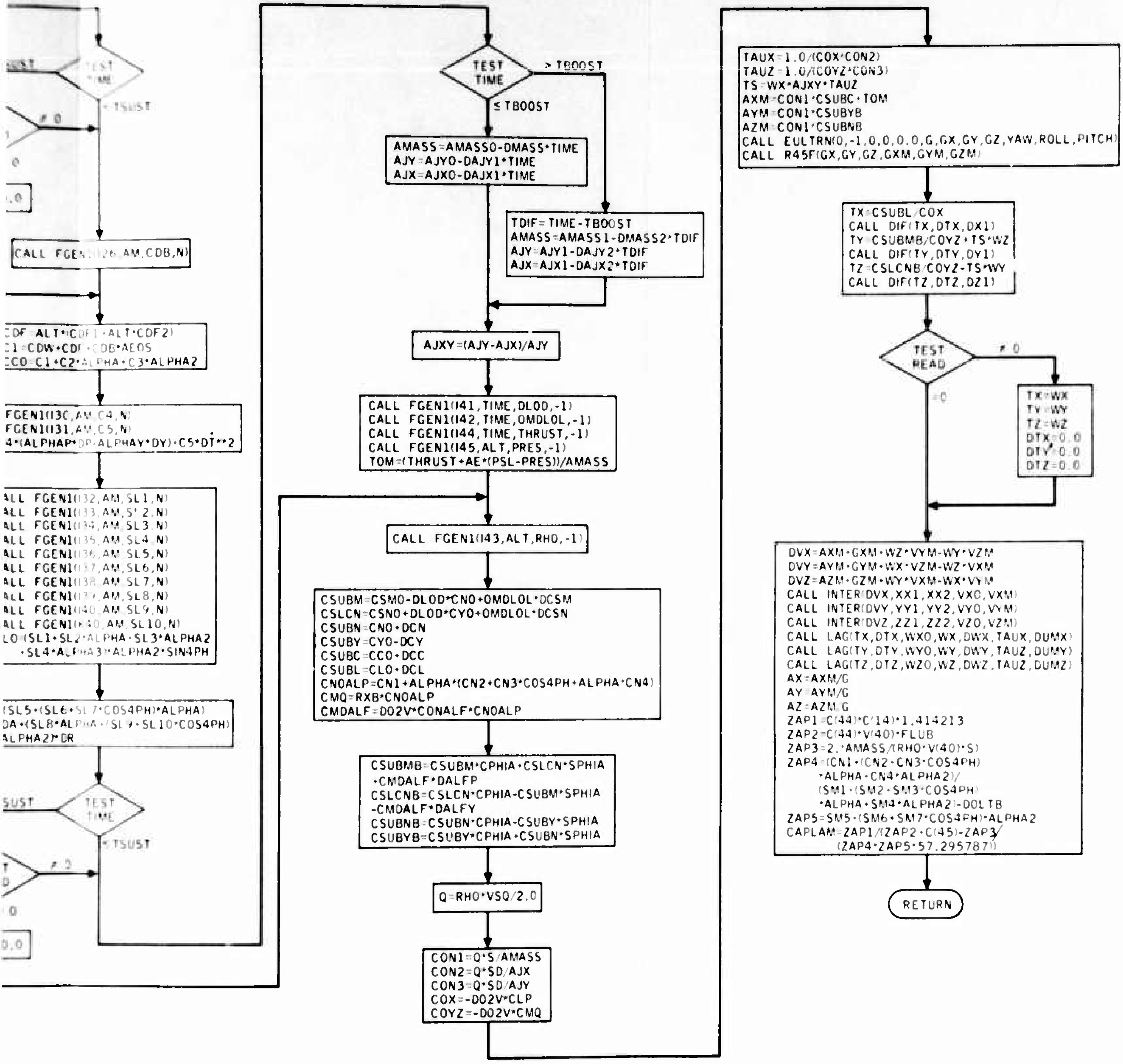

Figure 26. Aero Subroutine
Flow Chart

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TABLE XXIII. AERODYNAMICS (MAERO) SUBROUTINE

Name		Quantity	Units	Coordinate System
V(1)	RELALT	h_m, Missile altitude above ground	ft	Inertial
V(5)	DA	δ_a, Aileron deflection	deg	Missile
V(6)	DP	δ_p, Pitch deflection	deg	Missile
V(7)	DY	δ_y, Yaw deflection	deg	Missile
V(8)	VXM	V_x, Velocity X-axis missile	ft/sec	Missile
V(9)	VYM	V_y, Velocity Y-axis missile	ft/sec	Missile
V(10)	VZM	V_z, Velocity Z-axis missile	ft/sec	Missile
V(11)	WX	ω_x		
V(12)	WY	ω_y Components of angular velocity in missile axes	rad/sec	Missile
V(13)	WZ	ω_z		
V(14)	AX	A_x		
V(15)	AY	A_y Propulsive and aerodynamic acceleration	g	Missile
V(16)	AZ	A_z		
V(33)	ALPHA	α, Total missile angle of attack	deg	Missile
V(34)	ALPHAP	α_p, Missile pitch angle of attack	deg	Missile
V(35)	ALPHAY	α_y, Missile yaw angle of attack	deg	Missile
V(39)	Q	q, Dynamic pressure	lb/ft^2	
V(40)	VM	Total missile velocity.	ft/sec	
V(41)	AM	Missile Mach number		
V(44)	DWX	$\dot{\omega}_x$		
V(45)	DWY	$\dot{\omega}_y$ Scalar components of missile angular acceleration in autopilot axes	rad/sec^2	Missile
V(46)	DWZ	$\dot{\omega}_z$		
C(73)	S	S, Missile ref. area	ft^2	
C(74)	D	d, Missile ref. diameter	ft	
C(75)	PSL	P_{SL}, Sea level pressure	lb/ft^2	
C(76)	TBOOST	t_b, Booster burn time	sec	
C(77)	TSUST	t_s, Sustainer burn time	sec	
C(78)	ELTB	l_{TB}, Tail length (burnout)	ft	

TABLE XXIII. AERODYNAMICS (MAERO) SUBROUTINE (CONCLUDED)

Name	Quantity	Units	Coordinate System
C(79) XBAR	$\overline{X}$, cg to control surface trailing edge distance	ft	
C(80) CLP	C_{l_p}, Roll damping coefficient	1/rad	
C(81) AE	A_e, Nozzle exit area	ft^2	
C(82) AJXO	J_{xo}, Launch roll inertia	slug-ft^2	
C(83) AJX1	J_{x1}, End-of-boost roll inertia	slug-ft^2	
C(84) AJXT	J_{xt}, End-of-sustain roll inertia	slug-ft^2	
C(85) AJYO	J_{yo}, Launch lateral inertia	slug-ft^2	
C(86) AJY1	J_{y1}, End-of-boost lateral inertia	slug-ft^2	
C(87) AJYT	J_{yt}, End-of-sustain lateral inertia	slug-ft^2	
C(88) AMASSO	M_o, Launch mass	slugs	
C(89) AMASS1	M_1, End-of-boost mass	slugs	
C(90) AMASST	M_t, End-of-sustain mass	slugs	
C(91) TSEPAR	Burn time prior to launch	sec	
C(92) TGALT	Target altitude	ft	Inertial

TABLE XXIV. AERODYNAMICS SUBROUTINE

Intermediate Expressions (A)

$$C_1 = C_{D\omega} + (C_{DF1} + C_{DF2}\, h)\, h + \left| C_{DB} \frac{A_e}{S} \right|$$

$$\delta_T = \delta_p \cos \phi_a - \delta_y \sin \phi_a$$

$$\delta_R = \delta_y \cos \phi_a + \delta_p \sin \phi_a$$

$$\cos 4\phi_a = \cos (4\phi_a) = 1\text{-}8 \sin^2 \phi_a \cos^2 \phi_a$$

$$\sin 4\phi_a = 5.18 \left(\left|\cos \phi_a\right| - \left|\sin \phi_a\right| \right) \cos \phi_a \sin \phi_a$$

Secondary Expressions (B)

$$C_{mo} = m_1\alpha + (m_2 + m_3 \cos 4\phi_a)\, \alpha^2 + m_4\, \alpha^3$$

$$C_{No} = N_1\alpha + (N_2 + N_3 \cos 4\phi_a)\, \alpha^2 + N_4\, \alpha^3$$

$$\Delta C_m = (m_5 + (m_6 + m_7 \cos 4\phi_a)\, \alpha^2)\, \delta_T$$

$$C_{no} = (n_1\, \alpha^2 + n_2\, \alpha^3) \sin 4\phi_a$$

$$C_{yo} = (y_1\, \alpha^2 + y_2\, \alpha^3) \sin 4\phi_a$$

$$\Delta C_n = (n_3 + (n_4 + n_5 \cos 4\phi_a)\, \alpha^2)\, \delta_R + ((n_6 + n_7 \cos 4\phi_a)\, \alpha + n_8\, \alpha^2\, \delta_T)\delta_a$$

$$C_{co} = C_1 + C_2\alpha + C_3\, \alpha^2$$

$$\Delta C_c = (C_4\alpha + C_5\, \delta_T)\, \delta_T$$

$$C_{\ell o} = (\ell_1 + \ell_2\alpha + \ell_3\, \alpha^2 + \ell_4\, \alpha^3)\, \alpha^2 \sin 4\phi_a$$

$$\Delta C_\ell = (\ell_5 + (\ell_6 + \ell_7 \cos 4\phi_a)\, \alpha)\, \delta_a + (\ell_8\alpha + (\ell_9 + \ell_{10} \cos 4\phi_a)\alpha^2)\, \delta_R$$

$$\frac{d}{2V} C_{m_{\dot\alpha}} = \frac{d}{2V} (N_1 + \alpha(N_2 + N_3 \cos 4\phi_a + \alpha N_4)) \left(\frac{2\overline{X}^2}{3d^2} \right)$$

TABLE XXIV. AERODYNAMICS SUBROUTINE (CONCLUDED)

Primary Expressions (C)

$$C_m = C_{mo} - \frac{\Delta \ell}{d} C_{no} + \left(1 - \frac{\Delta \ell}{TB}\right) \Delta C_m$$

$$C_n = C_{no} + \frac{\Delta \ell}{d} C_{yo} + \left(1 - \frac{\Delta \ell}{\ell_{TB}}\right) \Delta C_n$$

$$C_N = C_{No} + \frac{d}{\ell_{TB}} \Delta C_m$$

$$C_y = C_{yo} - \frac{d}{\ell_{TB}} \Delta C_n$$

$$C_c = C_{co} + \Delta C_c$$

$$C_\ell = C_{\ell o} + \Delta C_\ell$$

TABLE XXV. AERODYNAMIC COEFFICIENTS IN MISSILE BODY AXES

$$C_{mb} = C_m \cos \phi_a + C_n \sin \phi_a$$

$$C_{nb} = C_n \cos \phi_a - C_m \sin \phi_a$$

$$C_{yb} = C_y \cos \phi_a + C_n \sin \phi_a$$

$$C_{Nb} = C_N \cos \phi_a - C_y \sin \phi_a$$

TABLE XXVI. EQUATIONS OF MOTION IN MISSILE BODY AXES

$$\dot{V}_x = \frac{qs}{m} C_c + g_x + \frac{T}{m} + \omega_z V_y - \omega_y V_z$$

$$\dot{V}_y = \frac{qs}{m} C_{yb} + g_y + \omega_x V_z - \omega_z V_x$$

$$\dot{V}_z = \frac{qs}{m} C_{Nb} + g_z + \omega_y V_x - \omega_x V_y$$

$$\dot{\omega}_x = \frac{qsd}{J_x} \left\{ C_\ell + \frac{d}{2V} C_{\ell p} \omega_x \right\} + \left(\frac{J_y - J_z}{J_x} \right) \omega_y \omega_z$$

$$\dot{\omega}_y = \frac{qsd}{J_y} \left\{ C_{mb} + \frac{d}{2V} \left(C_{mq} \omega_y + C_{m_{\dot{\alpha}}} \dot{\alpha}_y \right) \right\} + \left(\frac{J_z - J_x}{J_y} \right) \omega_z \omega_x$$

$$\dot{\omega}_z = \frac{qsd}{J_z} \left\{ C_{nb} + \frac{d}{2V} \left(C_{mq} \omega_z + C_{m_{\dot{\alpha}}} \dot{\alpha}_p \right) \right\} + \left(\frac{J_x - J_y}{J_z} \right) \omega_x \omega_y$$

$$J_y = J_z$$

TABLE XXVII. FUNCTION GENERATORS IN AERODYNAMIC SUBROUTINE

FGEN No.	Input	Output	Symbol	Units
I 1	ALT	SVEL	Sonic velocity	ft/sec
I 2	AM	SM1	m_1	1/deg
I 3	AM	SM2	m_2	$1/deg^2$
I 4	AM	SM3	m_3	$1/deg^2$
I 5	AM	SM4	m_4	$1/deg^3$
I 6	AM	SM5	m_5	1/deg
I 7	AM	SM6	m_6	$1/deg^3$
I 8	AM	SM7	m_7	$1/deg^3$
I 9	AM	SN1	n_1	$1/deg^2$
I 10	AM	SN2	n_2	$1/deg^2$
I 11	AM	SN3	n_3	1/deg
I 12	AM	SN4	n_4	$1/deg^3$
I 13	AM	SN5	n_5	$1/deg^3$
I 14	AM	SN6	n_6	$1/deg^2$
I 15	AM	SN7	n_7	$1/deg^2$
I 16	AM	SN8	n_8	$1/deg^4$
I 17	AM	CN1	N_1	1/deg
I 18	AM	CN2	N_2	$1/deg^2$
I 19	AM	CN3	N_3	$1/deg^2$
I 20	AM	CN4	N_4	$1/deg^3$
I 21	AM	Y1	Y_1	$1/deg^2$
I 22	AM	Y2	Y_2	$1/deg^3$
I 23	AM	CDW	C_{DW}	–
I 24	AM	C2	C_2	1/deg
I 25	AM	C3	C_3	$1/deg^2$
I 27	AM	CDF1	C_{DF1}	1/ft
I 28	AM	CDF2	C_{DF2}	$1/ft^2$
I 26	AM	CDB	C_{DB}	–
I 30	AM	C4	C_4	$1/deg^2$
I 31	AM	C5	C_5	$1/deg^2$

TABLE XXVII. FUNCTION GENERATORS IN AERODYNAMICS SUBROUTINE (CONCLUDED)

FGEN No.	Input	Output	Symbol	Units
I 32	AM	SL1	ℓ_1	$1/deg^2$
I 33	AM	SL2	ℓ_2	$1/deg^3$
I 34	AM	SL3	ℓ_3	$1/deg^4$
I 35	AM	SL4	ℓ_4	$1/deg^5$
I 36	AM	SL5	ℓ_5	1/deg
I 37	AM	SL6	ℓ_6	$1/deg^2$
I 38	AM	SL7	ℓ_7	$1/deg^2$
I 39	AM	SL8	ℓ_8	$1/deg^2$
I 40	AM	SL9	ℓ_9	$1/deg^3$
K 40	AM	SL10	ℓ_{10}	$1/deg^3$
I 41	TIME	DLØD	$\Delta\ell/d$	—
I 42	TIME	ØMDLØL	$1 - \Delta\ell/\ell_{TB}$	—
I 44	TIME	THRUST	Rocket motor thrust	lb
I 45	ALT	PRES	Ambient pressure	lb/ft^2
I 43	ALT	RHØ	Air density	$slug/ft^3$

2.3.11 Program Glossary

(U) A master program glossary defining all the elements appearing in both the V and C arrays is contained in Tables XXVIII and XXIX, respectively.

2.4 TYPE OF SIMULATION FACILITIES TO BE USED

(U) The only equipment that is required is the GE-635 or any other digital computer capable of compiling FORTRAN IV source decks. No training equipment or mockups are required.

2.5 INSTRUMENTATION

(U) None is required.

2.6 DATA REDUCTION AND ANALYSIS TECHNIQUES

(U) No special data reduction techniques are required.

TABLE XXVIII. MASTER GLOSSARY, V ARRAY

Name	Quantity	Units	Coordinate System
V(1)	hm, Missile altitude above ground	ft	Inertial
V(2)	δ_{ac}, Aileron deflection command	deg	Missile
V(3)	δ_{pc}, Pitch deflection command	deg	Missile
V(4)	δ_{yc}, Yaw deflection command	deg	Missile
V(5)	δ_a, Aileron deflection	deg	Missile
V(6)	δ_p, Pitch deflection	deg	Missile
V(7)	δ_y, Yaw deflection	deg	Missile
V(8)	V_x, Missile velocity X-axis	ft/sec	Missile
V(9)	V_y, Missile velocity Y-axis	ft/sec	Missile
V(10)	V_z, Missile velocity Z-axis	ft/sec	Missile
V(11)	ω_x, Angular velocity	rad/sec	Missile
V(12)	ω_y, Angular velocity	rad/sec	Missile
V(13)	ω_z, Angular velocity	rad/sec	Missile
V(14)	A_x, Propulsion and aerodynamic acceleration	g	Missile
V(15)	A_y, Propulsion and aerodynamic acceleration	g	Missile
V(16)	A_z, Propulsion and aerodynamic acceleration	g	Missile
V(17)	A_{zc}, Elevation maneuver command	g	Autopilot
V(18)	A_{yc}, Azimuth maneuver command	g	Autopilot
V(19)	ψ, Euler yaw angle	rad	
V(20)	ϕ, Euler roll angle	rad	
V(21)	θ, Euler pitch angle	rad	
V(22)	R_x, Seeker boresight range	ft	Seeker
V(23)	R_y, Seeker lateral range	ft	Seeker
V(24)	R_z, Seeker normal range	ft	Seeker
V(25)	ϵ_z, Tracking error angle, pitch	rad	Seeker
V(26)	ϵ_y, Tracking error angle, yaw	rad	Seeker
V(27)	ν, Seeker elevation gimble angle	rad	
V(28)	η, Seeker azimuth gimble angle	rad	

TABLE XXVIII. MASTER GLOSSARY, V ARRAY (CONTINUED)

Name	Quantity	Units	Coordinate System
V(29)	R_i, Horizontal longitudinal range component	ft	Inertial
V(30)	R_j, Horizontal lateral range component	ft	Inertial
V(31)	ϵ_{gz}, Gate error angle, pitch	rad	Seeker
V(32)	ϵ_{gy}, Gate error angle, yaw	rad	Seeker
V(33)	a, Total missile angle of attack	deg	Missile
V(34)	a_p, Missile pitch angle of attack	deg	Missile
V(35)	a_y, Missile yaw angle of attack	deg	Missile
V(36)	V_i, Horizontal longitudinal velocity component	ft/sec	Inertial
V(37)	V_j, Horizontal lateral velocity component	ft/sec	Inertial
V(38)	V_k, Vertical velocity component	ft/sec	Inertial
V(39)	q, Dynamic pressure	lb/ft^2	
V(40)	Total missile velocity	ft/sec	
V(41)	Missile Mach number		
V(42)	a_{cp}, Acceleration command pitch	g	Autopilot
V(43)	a_{cy}, Acceleration command yaw	g	Autopilot
V(44)	$\dot{\omega}_x$		
V(45)	$\dot{\omega}_y$ Scalar components of missile angular acceleration in missile axes	rad/sec^2	Missile
V(46)	$\dot{\omega}_z$		
V(47)	$\dot{\delta}_{ac}$, Aileron command rate	deg/sec	Missile
V(48)	$\dot{\delta}_{pc}$, Elevator command rate	deg/sec	Missile
V(49)	$\dot{\delta}_{yc}$, Rudder command rate	deg/sec	Missile
V(50)	Closest approach at end of flight	ft	
V(51)	Range component in Y seeker axis	ft	Seeker
V(52)	Range component in Z seeker axis	ft	Seeker
V(53)	ω'_x		
V(54)	ω'_y Missile body rates in autopilot axes	rad/sec	Autopilot
V(55)	ω'_z		

TABLE XXVIII. MASTER GLOSSARY, V ARRAY (CONTINUED)

Name	Quantity	Units	Coordinate System
V(56)	$\dot{\omega}'_x$ Scalar components of missile angular acceleration in autopilot axes	rad/sec^2	Autopilot
V(57)	$\dot{\omega}'_y$		
V(58)	$\dot{\omega}'_z$		
V(59)	A'_x Propulsive and aerodynamic acceleration components in autopilot axes	g	Autopilot
V(60)	A'_y		
V(61)	A'_z		
V(62)	V'_x Missile velocity components in autopilot axes	ft/sec	Autopilot
V(63)	V'_y		
V(64)	V'_z		
V(65)	Special test variable - used as system diagnostic		
V(66)	Total miss distance	ft	Miss Distance
V(67)	x component of range	ft	Autopilot
V(68)	y component of range	ft	Autopilot
V(69)	z component of range	ft	Autopilot
V(70)	y component of miss	ft	Miss Distance
V(71)	z component of miss	ft	Miss Distance
V(72)	x component of acceleration	g	Inertial
V(73)	y component of acceleration	g	Inertial
V(74)	z component of acceleration	g	Inertial
V(75)	y component of acceleration at blind range	g	Miss Distance
V(76)	z component of acceleration at blind range	g	Miss Distance
V(77)	Blind time in yaw channel	sec	
V(78)	Blind time in pitch channel	sec	
V(79)	Final line of sight angle (vertical)	rad	Inertial
V(80)	Final heading angle (horizontal)	rad	Inertial
V(81)	x component, LOS rate	rad/sec	Inertial
V(82)	y component, LOS rate	rad/sec	Inertial
V(83)	z component, LOS rate	rad/sec	Inertial
V(84)	Λ, Guidance gain		

TABLE XXVIII. MASTER GLOSSARY, V ARRAY (CONTINUED)

Name		Quantity	Units	Coordinate System
V(85)	DE	Total yaw precession rate		
V(86)	DEXS	Total pitch precession rate		
V(87)	E	Yaw gyro inertial angle		
V(88)	C1	Yaw look angle (indicated)		
V(90)	G1	Forcing function cross-coupled equation 1		
V(91)	DG1	Derivative forcing function cross-coupled equation 1		
V(92)	G2	Forcing function cross-coupled equation 2		
V(93)	DG2	Derivative forcing function cross-coupled equation 2		
V(94)	D1N	Integral forcing function cross-coupled equation 1		
V(95)	G2N	Integral forcing function cross-coupled equation 2		
V(96)	FFE	Forcing function yaw axis		
V(97)	DFE	Derivative forcing function yaw axis		
V(98)	FEXS	Forcing function pitch axis		
V(99)	DFEXS	Derivative forcing function pitch axis		
V(100) – V(110)		Not Used		

TABLE XXVIII. MASTER GLOSSARY, V ARRAY (CONCLUDED)

Name	Quantity	Units	Coordinate System
V(111)	Sum 1 - Tracker sampler bias	sec	
V(112)	TEAYD Tracker error yaw · RKAMG	deg	
V(113)	TEAPD Tracker error pitch · RKAMG	deg	
V(114)	TEAYS - Tracker ZØH output signal, yaw	deg	
V(115)	TEAPS - Tracker ZØH output signal, pitch	deg	
V(116)	VSYP - Tracker output signal pitch	deg/sec	
V(117)	VSPP - Tracker output signal yaw	deg/sec	
V(118)	TEYD - Tracking error - yaw	deg	
V(119)	TEPD - Tracking error - pitch	deg	
V(120)	UND Seeker elevation	deg	
V(121)	ETAD Seeker azimuth	deg	
V(122)	WXD		
V(123)	WYD Missile angular velocity	deg	
V(124)	WZD		
V(125)	XLOSD		
V(126)	YLOSD LOS Rate, inertial	deg/sec	
V(127)	ZLOSD		
V(128)	ANT (New)		
V(129)	ψ Yaw D		
V(130)	ϕ Roll D Error angle	deg	
V(131)	θ Pitch		
V(132)	DED Total precession rate, yaw		
V(133)	DEXSD Total precession rate, pitch	deg/sec	

TABLE XXIX. MASTER GLOSSARY, C ARRAY*

Name	Quantity	Units
C(1)	Not used	
C(2)	Autopilot activation time	sec
C(3)	Blind range, pitch	ft
C(4)	Gate error angle/$\frac{d}{dt}$ V (18)	$\frac{\text{mills}}{\text{g/sec}}$
C(5)	Blind range filter time constant	sec
C(6)	K_p, Angle restoration gain	g/deg
C(7)	β_o, Restoration angle bias	deg
C(8)	τ_β, Angle restoration filter time constant	sec
C(9)	Blind range, yaw	ft
C(10)	Not used	
C(11)	Not used	
C(12)	Not used	
C(13)	Half field of view, seeker	rad
C(14)	K_g, Guidance gain	g/deg/sec
C(15)	τ_a', Tracker time constant	sec
C(16)	Precession rate limit	rad/sec
C(17)	C_1 Seeker drift terms	rad/sec
C(18)	C_2 Seeker drift terms	rad/sec
C(19)	C_3 Seeker drift terms	rad/sec/g
C(20)	C_4 Seeker drift terms	
C(21)	C_5 Seeker drift terms	1/sec
C(22)	C_6 Seeker drift terms	1/sec
C(23)	C_7 Seeker drift terms	sec
C(24)	C_8 Seeker drift terms	sec
C(25)	C_9 Seeker drift terms	rad/sec/g
C(26)	C_{10} Seeker drift terms	rad/sec/g
C(27)	C_{11} Seeker drift terms	1/sec/g
C(28)	C_{12} Seeker drift terms	rad/sec/g^2
C(29)	C_{13} Seeker drift terms	rad/sec/g^2

*See Appendix V - Volume III - System Analysis Document for typical values of the C array.

TABLE XXIX. MASTER GLOSSARY, C ARRAY (CONTINUED)

Name	Quantity	Units
C(30)	C_{14}	rad/sec/g^2
C(31)	C_{15}	rad/sec
C(32)	C_{16}	rad/sec
C(33)	C_{17}	rad/sec/g
C(34)	C_{18} Seeker drift terms	
C(35)	C_{19}	1/sec
C(36)	C_{20}	sec
C(37)	C_{21}	rad/sec/g
C(38)	C_{22}	rad/sec/g
C(39)	C_{23}	rad/sec/g^2
C(40)	K_1, Tracking loop velocity gain	1/sec
C(41)	TG, Gimbal preload	g
C(42)	Drift control (set to 1.0 to include drift)	
C(43)	Autopilot lateral channel activation switch level	g
C(44)	K_a, Autopilot lateral channel gain	deg/g
C(45)	K_b, Autopilot damping gain	deg/deg/sec
C(46)	ϕ_K, Roll channel gain	deg/deg
C(47)	Acceleration limit, lateral channels	g
C(48)	Command limit, lateral channels	deg
C(49)	τ_{sn}, Lead time constant	sec
C(50)	τ_{sd}, Lag time constant	sec
C(51)	τ_{bn}, Lead time constant	sec
C(52)	τ_{YDLG}, Lag time constant	sec
C(53)	Roll channel deadtime	sec
C(54)	Roll rate signal limit	rad/sec
C(55)	τ_{ra}, Time constant in autopilot	sec
C(56)	Roll rate switch level	rad/sec
C(57)	τ_{acc}, Lateral channel time constant	sec
C(58)	τ_{RG}, Lateral channel time constant	sec

TABLE XXIX. MASTER GLOSSARY, C ARRAY (CONTINUED)

Name	Quantity	Units
C(59)	$\dot{\phi}_K$, Roll rate gain	deg/deg/sec
C(60)	Roll channel limit change time	sec
C(61)	τ_{r1}, Lead time constant	sec
C(62)	τ_{r2}, Lag time constant	sec
C(63)	Roll command limit	deg
C(64)	Roll command limit	deg
C(65)	Lateral channel rate limit	rad/sec
C(66)	Not used	
C(67)	Not used	
C(68)	Not used	
C(69)	Not used	
C(70)	Not used	
C(71)	Not used	
C(72)	Not used	
C(73)	S, Reference area	ft^2
C(74)	d, Reference diameter	ft
C(75)	Sea level pressure	lb/ft^2
C(76)	Booster burn time	sec
C(77)	Sustainer burn time	sec
C(78)	ℓ_{TB}, Tail length, burnout	ft
C(79)	$\overline{X}$, cg to flipper distance	ft
C(80)	C_{ℓ_p}, Roll damping coefficient	1/rad
C(81)	A_e, Nozzle exit area	ft^2
C(82)	J_{xo}, Launch roll inertia	$slug\text{-}ft^2$
C(83)	J_{x1}, End-of-boost roll inertia	$slug\text{-}ft^2$
C(84)	J_{xt}, End-of-sustain roll inertia	$slug\text{-}ft^2$
C(85)	J_{yo}, Launch lateral inertia	$slug\text{-}ft^2$
C(86)	J_{y1}, End-of-boost lateral inertia	$slug\text{-}ft^2$
C(87)	J_{yt}, End-of-sustain lateral inertia	$slug\text{-}ft^2$
C(88)	M_o, Launch mass	slugs

TABLE XXIX. MASTER GLOSSARY, C ARRAY (CONTINUED)

Name	Quantity	Units
C(89)	M_i, End-of-boost mass	slugs
C(90)	M_t, End-of-sustain mass	slugs
C(91)	Burn time prior to launch	sec
C(92)	Target altitude	ft
C(93)	Not used	
C(94)		
C(95)		
C(96)		
C(97)	Control surface servo gain	1/sec
C(98)	Control surface time constant	sec
C(99)	Control surface velocity limit	deg/sec
C(100)	Control surface angle limit	deg
C(101)	Control surface rate threshold	deg/sec
C(102)	Not used	
C(103)	Dual purpose input: Min. range of aimpoint wander when C(106) ≠ 0. Initial target acceleration when C(106) = 0. Subroutine bypassed when C(103) = 0.	ft g
C(104)	Dual purpose input: A, used in aimpoint wander when C(106) ≠ 0. Final target velocity when C(106) = 0.	ft/sec
C(105)	Dual purpose input: PLØTK, used in aimpoint wander when C(106) ≠ 0. Boresight range at which target motion starts when C(106) = 0.	ft
C(106)	PHØTØK, used in aimpoint wander	
C(107)	Not used	
C(108)		
C(109)	LOS memory threshold in guidance law	deg
C(110)	G-Bias	g
C(111)	LOS memory gain in guidance law	g/deg

TABLE XXIX. MASTER GLOSSARY, C ARRAY (CONTINUED)

Name	Quantity	Units
C(112)		
C(113)		
C(114)	TB Sampling time (function of distribution to target (0.0800)	
C(115)	TC Sampling time control (0.1000)	
C(116)	3S - Gyro rotor speed	rad/sec
C(117)	K2T - Precession torque coefficient	gcm/V
C(118)	Dump program control logic	B = 0
C(119)	- Rail control logic	S = 1.0
C(120)		
C(121)		
C(122)		
C(123)		
C(124)		
C(125)		
C(126)	Not used	
C(127)		
C(128)		
C(129)		
C(130)		
C(131)		
C(132)		
C(133)	PSIPØ LOS Memory threshold guidance law	deg
C(134)	BP - G-Bias	g
C(135)	AKSIGP LOS Memory gain in guidance law	g/deg
C(136)	GNUT - Program logic control - W/0-0, W = 1.0	
C(137)	DFR Coulomb friction drift factor	
C(138)	DST Spring torque drift factor	
C(139)	DSU Unbalance drift factor	
C(140)	DAN Anisoelastic drift factor	

TABLE XXIX. MASTER GLOSSARY, C ARRAY (CONCLUDED)

Name	Quantity	Units
C(141)	DDU Dynamic unbalance factor	
C(142)	SK Torquer gain coefficient	V/deg/sec
C(143)	AKT - Tracker gain constant	1 sec
C(144)	TS - Sampling period	sec
C(145)	OMEGLD - Precession rate limit	deg/sec
C(146)	GKK - Guidance gain	g/deg/sec
C(147)	BIAS - Sampling rate offset bias	sec
C(148)	TLDP - Tracker filter lead time constant - Pitch	sec
C(149)	TLGP - Tracker filter lag time constant - Pitch	sec
C(150)	TLOY - Tracker filter lead time constant - Yaw	sec
C(151)	TLGY - Tracker filter lag time constant - Yaw	sec
C(152)	SPOT - Tracker spot size	Ft
C(153)	CF1 Friction factor coefficient	
C(154)	CF2 Friction factor coefficient	
C(155)	CF3 Friction factor coefficient	
C(156)		
C(157)		
C(158)	Not used	
C(159)		
C(160)		

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13. ABSTRACT

(U) The objective of the engineering design study of the close air support weapon (CASW) was to provide design considerations for the new close air support missile (CASM). The derivation of the missile was undertaken based on the modification of an existing missile. This study incorporates operational requirement and warhead effectiveness studies for various close air support targets leading to warhead and launch envelope recommendations. A thorough analysis of the system performance and terminal accuracy was conducted. Missile simulation models and a system description, including missile, launcher, avionics, and aerospace ground equipment (AGE) are provided. A cost analysis exercise was conducted for the design, development, test and evaluation (DDT&E) and production of the candidate approach. This report consists of six volumes: Management Summary, Operational Analysis and Warhead Effectiveness, System Analysis, System Design, Cost Analysis, and Missile Simulation.

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